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REPORT ON THE UNIFICATION OF MATHEMATICS IN THE UNIVERSITY HIGH SCHOOL.[1]

BY G. W. MYERS,
The University of Chicago.

It is granted at the outset that the problem of improving the teaching of high-school mathematics is very much more a problem of improving the teacher than the texts. The School of Education is earnestly and systematically striving to improve both. No material can be so happily organized as to guarantee good results from poor teaching. No theory of teaching, or organization of subject-matter can make a bad teacher a good one. It is granted at once that with good teaching, excellent mathematical results can be obtained with the conventional type of high-school text, with which all are familiar. But it is not too much to claim that we may expect at least very radical improvement on the existing status from that happiest of all combinations, good teachers and good text-book material. The problem of better material is then very far from being an inconsequential problem.

Furthermore, it is readily admitted that the question: What is a good (by this is meant the best possible) text-book for high-school algebra, or geometry, or trigonometry? is very far from being a solved problem. By taking up the discussion of our experiences in the University High School with texts on a unified type of material, I am not even claiming that I am convinced beyond conversion that the best type of high-school texts will be found to be any sort of organization of unified material. I am however convinced that the best teaching of mathematics to secondary pupils that I have ever seen was with the use of unified material in the teaching process, although in the texts used the subject-matters were developed separately. The teacher did the unifying. But the teacher was a past master of both mathematics and of educational theory and practice. So

[1] Given before the Mathematical Club of the University of Chicago, August 29, 1911.

far as my experiences have gone, I believe now that in many respects unified mathematical material has distinct advantages over the separate types of treatment, and that with a really professional use of such material there is no serious countervailing loss in other respects. I am bold enough to say that the books we are using have been at least an important factor in enabling our teaching to make a distinct step in a good direction.

Those of us who are engaged in the practical phases of the problem of adapting subject-matter through class-room trial and test to high-school uses are not now claiming and have not at any time claimed even that the best type of fusion material has been worked out, still less that textual fusion is now *proved* to be the thing to be sought. We are working on the problem with some success at least.

Finality is very far from our thought. New experiences and occasions teach new possibilities and new duties. The horizon rises and broadens rather than closes down into a finality. It is a virgin field and the soil of course productive.

We began preparing mixed material from algebra, geometry, and arithmetic five or six years ago. Our plans had very little influence on classes until over a year later. After two years, for the benefit of our own pupils merely, and at the instigation of the then dean of the University High School, we were induced to print in book form the material we had collected and were then using. This book of little more than notes formed the first edition of "*First-Year Mathematics,*" and it was printed in provisional form merely to meet the practical exigencies of our own situation.

When first-year students had completed these notes we were face to face with the problem of what to do with them in the second year. After considerable discussion and some trial we decided to use one of the common texts in plane geometry, and to supplement it with geometric exercises for algebraic solution of our own collation and manufacture. This supplementary material was printed by the University Press under the title just mentioned, and second-year classes had it in their hands as a collateral text. These exercises sought to hold the ground in algebra gained during the first year, while plane geometry was being learned, to enable the pupil to use algebraic notions, notations and methods in his geometric work, to impress him that algebraic modes of thought and work were valid anywhere in

mathematics, and lastly, to gain a little new algebraic ground along with plane geometry. I submit that while we were doing this we were getting experience with a rather favorable type of parallel work. The plan was a provisional one, was designed as such, and was abandoned not because it was ineffective, but because we wished to move on to what we deemed then and deem now the better plan of a more definite and fuller fusion type of work.

But the parallel work was the type of second-year work during two or three years while we were revising, extending, and amplifying the material of our little book of preliminary notes into the present text *"First-Year Mathematics."* This text was put into the hands of our classes three years ago. Since then first-year classes have used a text which puts notions of arithmetic, algebra, and geometry together.

Encouraged by our work with first-year classes we set about a more intimate interweaving of the algebra and geometry for the second year, and the text, *"Second-Year Mathematics,"* which resulted has been in the pupils' hands only one year, though during a part of year before last preprints of the present text were used by students. Let us say then, that adverse criticisms, which have been rather plentiful this summer, as to the educational worth of the fusion type of mathematics judged on the basis of college entrance experiences of our graduates, are both hasty and unfair. Students who have had a systematic treatment of this type of work ought at least to be permitted to reach high-school graduation before they are weighed in the college entrance balance and found wanting. There are as yet no relevant facts pertaining to college entrance tests from our pupils either for or against this type of training. A few who have had this treatment in a fragmentary and spotted form, and who have left us with the lowest possible high-school mathematical record, have traveled a rocky road both through college gates and afterwards. But this is neither novel nor merely recent, nor will it disappear hereafter, no matter what the ultimate issue of unified mathematics may prove to be.

Snap judgments from those who find it difficult to await the slow evolution of educational plans have been passed upon us many times. Always, too, these judgments are passed in ways and at times such that an answer from us is impossible. All we are doing, or can do just now, is "standing pat," working quietly and energetically, in the confident hope that in the fullness

of time facts pertaining to collegiate entrance, which even to those who find no other satisfactory way of judging of the mathematical output of the high school, may have a real bearing and convincing force touching the fusion plan.

It would perhaps be more scientific, and it would certainly be safer for me, if I should refuse to discuss the question of our experiences with mixed mathematics until some later occasion; for the very fact of my appearance on this program to discuss the topic before us will be construed by some to mean that I am committed to the view that the fusion type of mathematics, in the form which we now have it, has been demonstrated to be the supreme need of the hour. I wish to disclaim that this is my attitude toward the question. I must also hasten to say that my recent study of actual class-work in France, Germany, and England brought me into contact with a great deal of this type of work, and that through both observation and experience at home and abroad, I have acquired a strong bias in favor of it.

I may say that the dominant phase of European secondary mathematics is of the mixed, or parallel, or quick alternation type. If we could claim as great a measure of success for our secondary mathematics teaching as European teachers may justly claim, we should be claiming something that is very much superior to anything I have seen or heard of in our own high schools, public or private. He who says we have nothing to learn from foreign mathematical teaching practice is suffering under a case of professional astigmatism.

It is also true that in places where the fusion type of mathematics has been tried in our own country under at all favorable circumstances, the results have been highly satisfactory. As one who has given close attention to the mathematical work in our own high school, but also as one who has not taught any of it, I am ready to claim for it many mathematical virtues and qualities that are at least more distinctly discernible now than was the case under the conventional mode of procedure we were following before we took up this type of work. I will not be understood to be claiming too much if I undertake to enumerate some of these points of excellence, and perhaps succeed partially in an attempt to connect them with the fusion type of work we are calling unified mathematics.

Indeed, I believe there are ways of judging of the character and results of secondary mathematical teaching that are more ade-

quate, fairer, and more generally satisfactory than are the issues of college entrance tests. Specific aim and purpose, and point of view count for so much in many universities and vary so greatly from one institution to another as to impair greatly the broad educational worth of these tests. Very often an institution which trains with reference to certain technical lines in which specific mathematical topics are of particularly great importance, allows its entrance tests to take on a markedly technical bias toward a narrow range of topics, in which rightly trained, high-school students ought not to be expected to be qualified. One of these better ways is to gauge the attitude of pupils while yet in the high school, toward mathematical study. I am sure that in our school there has been a marked improvement in the pupil's friendliness toward mathematical work, in his belief in its worth, and in his confidence that he has at least *some* mathematical ability.

We hear much less frequently than formerly from the principal's office of pupils seeking by direction or indirection to get exemption from mathematical classes. Parents who detect in their children even at very tender ages that marked artistic and literary temperament that some like to think so repugnant to dealing profitably with the cold and stern realities of mathematics, seem to be belaboring the officials for surcease of mathematical sorrow with less penetration to the mathematical supervisor than was formerly the case.

There come to us from the pupils, statements made to one another, to their parents, and to their teachers, that are distinctly encouraging to those who are endeavoring to make a better mathematical atmosphere in the school. Perhaps I will have covered this point sufficiently by saying that the general mathematical atmosphere, both pupil-made and teacher-made, is more favorable now than it was a few years since, and this is particularly noticeable among the early classes. The improvement in this regard is almost contemporaneous with our change of plan.

In the next place, pupils submit themselves more readily and freely than formerly to the searchings of teachers for reasons for their procedure. They even enjoy the submission, for they like to show that they know the reasons, as well as the results, and conclusions when this is expected of them. In the geometry classes we do not hear such things as; "I am not expected to know that, for that is algebra, and I have finished that subject,"

nor do we hear similiar remarks in third-year algebra classes about geometry. Pupils expect that teachers will require rational accounting for mathematical inferences and conclusions, and accept the situation with good grace. An inquiry for reasons is no longer regarded as a reflection on their honesty, or an impeachment of their honor. They understand that geometrical explanations of algebraic difficulties, or algebraic explanations of geometrical matters are accepted as rational, even in cases in which the teacher insists on a certain type of explanation. They take a very much less narrow and restricted and a much more natural attitude in attacking a problem. They undertake to bring any mathematical knowledge they have to bear on any sort of problem that arises. Oftentimes they say, "Wonder whether this problem will be easier by algebra or by geometry." This remark indicates to me that pupils are learning what the algebraic way is and what the geometric in a dynamic way through their toolage values, by keeping the subject-matters together, and so to speak "hefting" these ways one against the other. Such learning is not rote-learning, and *memoriter,* but real.

Then we detect an improvement in what I may call mathematical versatility, the ability to tack sail when a chosen course seems not to be leading to a successful issue. The disposition as well as the ability to shift the ground of attack is discernible to one who watches the work for a brief time. The disposition not to cry, "Too hard," and give up when the first attempt does not succeed is plainly noticeable. It looks much like an increase in mathematical tenacity.

A fourth improvement: Ordinarily when a high-school pupil is told that some demonstration or proof he thought he had made correctly yesterday is in fact wrong he receives the blow with perfect composure, not to say nonchalance. He does not seem to take such news to heart to the extent of manifesting any disposition to defend his thinking. He cares little one way or the other about it, because he feels altogether shaky about his real understanding of reasons for things. More than once, and more frequently than formerly have I seen our pupils manifest unmistakably the disposition to defend their positions when their procedure has been called unwarrantable, or their conclusions challenged. They seem to have greater mathematical self-confidence or self-reliance, and care more for their own attempts and ways of handling difficulties than they did formerly, even in classes taught by the same teachers that formerly taught them. I feel

that a good part of this is due to the spirit begotten of the watchword: "Any way so that it is a right way." Perhaps this is another phase of the greater mathematical tenacity developed by the plan.

A fifth improvement, not so easily traceable to the type of material used, is the diminution in the number of failures. There was common remark before the examinations at the close of the last semester, from the teachers and particularly from the officials of the high school, that the examination questions, in the formulation of which I had a hand, were too difficult. I was urged to go over the question papers again to see if I could not consent that they were too difficult. I went over them again very carefully and replied: "I do not think they are too difficult." The examinations were then given without change, and it was common remark afterward, brought to me by persons who wanted me to hear it, that the number of failures was comparatively and gratifyingly low—some five per cent lower than is customary. Whatever significance this rather short range fact has, and when called upon to give our experiences while they are yet young we must use short range facts, it is to the favor of the type of work used, in so far as such a result does not arise from accident, better teaching, or a better quality of pupil to be taught.

Another point which in my opinion has its connection with the unified type of work is that the modes of presentation are very much more graphic and vivid than is customary in courses in algebra in secondary schools. Teachers find themselves more or less unconsciously illustrating algebraic things by geometric sketches, and pupils get into the habit of trying to use things to picture and clear up abstract algebraic forms. The graph has become a more systematic and homogeneous element in the general scheme of teaching, both the aspect of the graph involved in pictured exhibits and presentations as well as the analytic type of the graph. Through the manifold use of lines, rectangles, solids, and so on, to illustrate algebraic processes and results, through the close association of the algebra with the geometry the pupil develops the disposition to picture any conditions that bother him, and his attempts thus grow more and more natural and stronger. The habit of clearing the ground for action by the use of drawings and diagrams actually becomes a part of the pupil's way of studying. He studies his algebra with his pencil in hand in a fuller sense than merely to write down the

necessary equations. I have actually seen the children using geometry and pictured forms to explain difficulties to one another in unexpected ways. I regard it as practically settled that algebraic study gains immensely in clearness, vitality, and interest through unified material, and as this subject is the sore offender of the public in high school mathematics, this is no small gain.

But geometry also gains from this mode of treatment. Pupils acquire greater flexibility in designating geometric magnitudes, geometric equations written in algebraic symbols mean more to them and can be reasoned about more cogently; they feel that there is more in geometrical truths when they may be used to furnish algebraic equations leading to solutions. To prove $\angle ABC + \angle BCA + \angle CAB = 180°$ and then leave it until some geometric proposition or problem calls for its use, means distinctly less than if it is applied at once to such as: $x+x+x=180°$, find x; $x+2x+3x=180°$, find x, and so on. Some parts of geometry become much more lucid by the aid of algebra; as for example, such matters as the generalized Pythagorean proposition, the area of a triangle in terms of its sides, and so on.

What I have said above perhaps means that pupils manifest a great deal more fertility in the use of *extemporalia*. Let me emphasize this point a little. They make frequent use of edges, corners, and physical objects seen in the class room to illustrate geometrical matters. They seem to think their mathematics into things, and to draw their mathematical thinking from real situations very much more than they did formerly. Their eyes are being opened more largely toward problematic situations and mathematical opportunities in the world about them. This makes for solidity and seriousness of thought in the subject. It is partially due to the more or less informal procedure at the beginning, and to the fact that the fusion plan emphasizes these tactics continuously to both teacher and taught. I believe also that it is largely due to the double track route that is always more or less obvious to the learner with every form of problem that is set for him.

All this means much for what we like to call mathematical efficiency. Perhaps if teachers had gotten some sort of rebirth of enthusiasm under the old plan, these same things might have been accomplished. But is the old so sacred that the educational problem must ever be circumscribed to the form of finding how to improve by holding continually to everything that has forced

upon us the painful need of improvement? May we not at least change the time of presentation and exposure time of the same old truths, without facing that fearful charge of thinking ourselves reformers, and revolutionizers, and upstarts? But even if we must bear the stigma of such charges, is it not better to do so than to acquiesce in low potential work and low efficiency of output? I do not believe it is overstating the case for unified mathematics to say that a good deal of this increase of enthusiasm in teaching and learning mathematics originated in the introducton of this changed type of material.

It is held by some who have tried both plans that pupils can more easily give summaries or synopses of the essentials of a subject when the work treated is confined to pure algebra than can be done under the fusion type of treatment. I am disposed to concede that this is true; still I do not believe that as algebra courses are usually taught in our secondary schools, the synoptical or summarizing feature of teaching actually has much place. That it is important, even highly important, is certainly true. Even with the conventional matter much improvement would come by more attention to making synopses of work gone over. I am prepared to admit that, inasmuch as the chief mental act called for in this type of study is remembering or recalling what has already been taught, the compartmental plan may adapt itself a little more readily to this particular phase of teaching. Facts drawn from a narrow field are more easily memorized. Furthermore, the chief benefit derived from synoptical studies of subjects is the aid given the memory in getting a firm hold of the subjects through seizing the main principles clearly and organizing with reference to them. With but little more difficulty, however, synoptical studies can be readily managed under the unified plan.

It will also be generally admitted that the teacher who relies mainly on memory in teaching mathematics will always prefer the compartmental plan. The narrowed, highly organized, clearly exhibited field is a much easier one to grasp in a memory way. The fusion plan must make its strongest appeal on the ground that the reason and the understanding are to be reached by the teaching, and to be exercised by the taught continuously from the very beginning of mathematical study if the study is to be worth much to the pupil. It is admitting only what the plainest manifestations of teaching procedure exhibit, to concede that we have not yet succeeded in any very large measure in

secondary work in finding routes as short and speedy through the fields of elementary mathematics by way of the reason and the understanding as are already pretty plainly charted by way of the memory. This is why the old-fashioned drill master and memoriter pedagogue die so hard. Only a minority of secondary teachers of mathematics as yet practice the doctrine that it is the *rationale,* not the technique, of mathematics that really educates.

We need very much to learn, also, how to appreciate *quality* of results of mathematical work in the high school, and how to estimate qualitative characteristics, rather than mere quantity of results. Perhaps it is expressing the situation more accurately to say, we have yet to learn how to appreciate and to estimate actual quality as well as quantity of teaching results. We need to take more and more to heart that, while quantity of mathematical matter may succeed in getting a pupil into college, only quality will enable him to maintain himself with credit to his antecedent training once he is admitted.

I should say that even when reasoning has been made the fundamental activity upon which mathematical teaching in the high school proceeds, there must be much attention given to synopses and resumes of subjects and topics, and that these particular phases of good teaching are more easily managed under the separate subject plan than under the fusion plan. They can, however, be managed under the fusion plan and of course there is all the more need for them under this plan. I do not, however, concede that this particular advantage of the separate subject plan is anything like so great as the advantage gained in other ways from the fusion plan. The synoptical resumes are the precise phases of study that must always be the legitimate business of memory, and they constitute the sphere of the memory rôle of mathematical study under any plan as to subject matter. The fusion plan is very far from eliminating the rôle of memory in mathematical study. It only subordinates it to the legitimate office of the pack horse of thought.

Our fourth year review course of one hour per week is planned with the thought of making a special feature of synoptical and summarizing studies of work that has already been carefully taught. It is not intended that this review shall be merely a rehearsal of the matter and method of the work covered during the first two years of the high school; the particular benefit that it should bring to the pupil is that which comes

through the making of synoptical exhibits and presentations of what is already more or less familiar material.

One would think this fourth year review course of one hour per week should commend itself on its face to the parents whose children have had no systematic mathematical work for a year, and nothing but this review work during a second year, and this period of mathematical inactivity, too, coming just before the pupils submit themselves to the test for college admission. It would seem so plain that former knowledge should be refreshed and the hold upon it somewhat strengthened, as a profitable preliminary for the coming tests, that parents would be the first to want their children to have it. As a matter of fact, many parents object very strenuously to what they call burdening their children with mathematics after they have completed the two years commonly required for college admission. Their argument is that the educational tendency of the time is to reduce rather than extend the time to mathematics, and that if the fusion procedure makes necessary an additional review course the plan in itself must be both reactionary and wasteful.

We claim also that even though the conventional plan of first year algebra and second year plane geometry were followed we would want this review course quite as much as we do under the fusion plan. In fact, the thought of the review course grew out of the feeling of a necessity of some such procedure before we had passed to the fusion plan. It was simply held over from a former epoch, and we have not yet been willing to yield time that was already assigned us. It is even more needed under the old plan than the new, so that it is in no sense reactionary and no more wasteful than the old plan was. We never set out to show that unified mathematics would make possible a reduction in the program time, already too much reduced, allotted to mathematics.

So that, even the objections that are made to this review course are not tenable as against the fusion plan.

It is my carefully formed opinion that the most successful procedure for secondary mathematical work would be a plan of fractional courses covering in the aggregate the same number of hours as does the present mathematical curriculum in the public high school but extending entirely through the four years. Mathematical power and skill are monotone increasing functions of the time, and the increase is by some power rather than by an increment. My view is not shared by the majority of

the mathematical members of the university high school faculty, and, hence, we do not follow this plan of fractional courses. Furthermore, it is not advisable to experiment in too many directions at the same time. We still have people to convince that unified mathematics is best for the high school.

Teachers in charge of classes say pupils do so much forgetting during the days on which they do not recite in mathematics, that so much more reviewing and rehearsing on what it was thought had been taught is necessary, that the method of fractional courses for high school pupils is wasteful and otherwise generally unsatisfactory to the teacher. To me the first part of this objection means only that the amount of forgetting becomes more obvious, more plain to the teacher under the fractional course plan, and it would seem it becomes plain at a time when the teacher may remedy the lack. In other words, the teacher merely sees more plainly how little of what he thought he had taught has really become a part of the pupils' thinking, has been really learned, and, this revelation is both wholesome for teacher and highly profitable to the taught. Both teachers and taught undeceive themselves more frequently under the plan of fractional course, and come to feel what real teaching and learning are.

What has become a real intellectual asset is not forgotten. What is merely held on to by memory may be retained long enough to pass final examinations, if they come only a few days after the work is closed, so that a very weak pupil may even make a good record in these examinations. Then the forgetting, under the present plan of condensation in the first two years, instead of coming at a time when the teacher might make amends for it, comes during the two years when the pupils do no systematic mathematical work under mathematical teachers. And thus the memory hold relaxes and the disappointing results show just at the time that is most painful and most unfortunate for the pupil who goes on to college. Forgetting is also a monotonic increasing function of the time.

But I am not asking that the fractional course plan should be used primarily because it is good for those who go on to college. It is quite as important that those who expect their educational work to end with the high school should really understand what is taught them, and should be able to reason in terms of it, that what they have learned should become at least a somewhat per-

manent mental asset, as it is that the student who is going on to college should have such a hold on his mathematics.

That the fusion type of mathematics does result in a more rational grasp of the subject seems certain. In the questions we have set from time to time as the work proceeds, and particularly at the ends of the semesters, the problems and questions that call for thinking are handled much more satisfactorily now than they were formerly.

In my opinion, the examinations prove, without any reference to what students may be able to do when they go to college, that pupils really grasp mathematical thought very much more effectively when they have been taught on the plan in question.

Another point worthy of mention here is that one kind of thinking that makes up a very important part of mathematical thinking is discriminating, or recognizing differences between subjects and topics. Of course, the summarizing of the subjects and topics helps a topic to stand out somewhat as an entity, and in such exercises the pupil gets practice in recognizing both what it is not, and what it is. I believe that this training in recognizing differences in things is of only secondary importance to the recognition of the essential unities of topics. It is even a condition precedent to the recognition of unities. Now one of the best ways to train the unformed faculty of discrimination is to handle classes of ideas that in some respects are markedly and recognizably different. The geometrical material and the algebraic material studied together, and contrasted as well as compared, furnish the qualifications of excellent material for training the immature powers of mathematical discrimination. The differences are more marked in many respects than is the case with the several topics and subjects of algebra *per se*.

For beginners, therefore, the mingled type of material offers distinct advantages in this very important sort of training.

I close, then, somewhat as I began, by saying that we are at present perhaps only midway, maybe not even halfway across the stream of difficulty in organizing subject matter of highest grade efficiency for secondary pupils. We are not yet ready to state the relative values of methods and plans decisively. I am hoping that we may never be willing to state these matters dogmatically.

I still think it would be more seemly to wait until the arguments *pro* and *con* have had an opportunity to become more objective in character and more convincing in force to take on

a somewhat longer range, and truer perspective, before reviewing them in public. But when the high compliment of being asked to state to you who are quite as much interested in the mathematical teaching situation as I am, what our experiences to date have been with the fusion type as we are really handling it, I cannot be so impolite as flatly to reject the compliment.

I have endeavored to be frank with you and to leave about the same degree of indefiniteness as to the merits of the fusion plan as against the standard plan as exists in our own minds. We are not proselyting for any method or any type of subject matter. We are altogether too painfully aware of the difficulties and dangers involved in a campaign of proselyting for a method that is not generally known to possess the elements of general applicability and practicability under the circumstances existing to guarantee its universal success by those who adopt it. We know too well that no really excellent teaching plan can be fool-proof.

I believe also that the matter of fusion mathematics would be in grave danger of being found unsatisfactory to teachers and to school officials, even after the fusion has been completely and perfectly made, if it does not have the thorough approval so far as it can have it a priori from the teachers who are to try it out. Readiness to be convinced is an indispensable condition to becoming convinced.

It is always safest, of course, to advocate that a procedure that departs from the conventional be first tried by good teachers, teachers eminently qualified in scholarship as well as in native teaching tact. In the hands of such teachers I am satisfied that even the fusion type of material contained in our high school texts will be a success.

This, however, is a modest claim, for I have already conceded that almost any kind of mathematical material can be made both interesting and profitable by a thoroughly interested and thoroughly capable teacher. Personal love for the subject, a reasonable degree of scholarship in the subject, seasoned with a fairly good allowance of native teaching tact, will succeed anywhere, and with almost any kind of mathematical material. I am of the opinion, however, that the measure of success will be greater with organically unified subject matter than with the conventional type, even when the latter is made to squint a little toward mixing, as in some texts now appearing.

THE EVALUATION OF PI IN ELEMENTARY GEOMETRY.

By A. J. Schwartz,
Wm. McKinley High School, St. Louis, Mo.

At a recent conference of high school teachers of mathematics the writer observed a tendency to omit the evaluation of pi in elementary geometry.

Omissions in geometry are popular nowadays; certainly not without reason, for many of the current text-books are unscientific, especially in their treatment of the mensuration of the circle, and they are frequently quite as bad from a pedagogical point of view.

In support of the first part of this statement it is sufficient to refer to the counterfeit demonstration regarding the length of the circumference of a circle, which still finds a place in some of these texts; and as to the latter, the writer merely asserts from experience that the one-sided evaluation of pi found in some of these same texts, wherein are computed only the perimeters of inscribed regular polygons does not develop in the minds of pupils a sufficiently clear and real conception of limits as applied in this important calculation.

Moreover, the usual arrangement of theorems is faulty for it tends to obscure the central theme of this topic. As presented in some of our most popular texts, that part devoted to this subject is a jumble of propositions on regular polygons and circles. Thus, in the midst of the propositions leading up to the evaluation of pi, one finds the propositions regarding the inscription of a regular decagon and of a regular pentadecagon. The insertion of these two wholly irrelevant propositions at this time is disconcerting to say the least; it interferes with the continuity of thought, and the effect is just as bad at this point as would be the effect of inserting irrelevant propositions between the subsidiary theorems leading up to the area of a rectangle.

It appears to the writer, however, that the desire to depart from the text may lead to most unwise ommissions. Referring to the case cited, in the writer's opinion, if pupils are forced to grope their way through the maze of bewildering abstractions regarding the relations of regular polygons and circles only to have the entire structure collapse at the very pinnacle by the teacher announcing the value of pi dogmatically or even empirically the best part of this topic is lost to the pupils. For, to the average high school pupil, the only educational value of

this topic worth mentioning is the cultural value since the facts involved have already been learned in arithmetic. But if culture means anything in this connection it means the acquisition of ideas and appreciation of principles.

Is not an intelligent appreciation of the principle of limits or of exhaustions a worthy end, transcending all others in importance in this topic? This appears to the writer to be the only excuse for introducing this topic into elementary geometry. However, unless a pupil has a complete visualization of the whole development, including the actual numerical evaluation of pi, the theory is of little significance to him and the preliminary theorems are without sense.

The actual numerical evaluation of pi is the *denouement* of the story of the circle; it is the unraveling of mysteries, and therefore, in the writer's opinion, it cannot be omitted without seriously impairing the understanding of that which precedes it.

It is the writer's belief that the numerical evaluation of pi presents the best opportunity we have in geometry for developing in the minds of our pupils a clear conception of limits as applied in mathematical investigation. To compute two numbers which differ less and less as the approximation continues; to observe that these numbers are identical to two places of decimals, and then to three places of decimals, and so on, is far more convincing to high school boys and girls than any amount of theory regarding limits.

It is true that the formula usually developed for performing these computations is beyond the algebraic accomplishment of the average second year pupil. But is the formula necessary or even desirable? In the writer's opinion it is not. In the first place the computations may be performed by a series of short steps; and in the second place, where pupils are not skilled in algebraic manipulation the sequence of steps involved in the formula is rendered obscure by its complexity, thereby creating a barrier to a complete visualization of the process. To use a homely illustration, if one wishes to acquire a thorough appreciation of the principle of weaving he will acquire a far better grasp of the principle by watching a Navajo Indian blanket weaver than by observing the working of a modern loom. As the bystander cannot comprehend or visualize the articulation of the parts of the complex, textile machinery even though he sees them put in place, so the unskilled schoolboy with the com-

plicated formula. This power is a matter of growth and cannot be acquired in a day.

Realizing this handicap it has been the writer's practice for some years to have his classes perform these computations gradually, by easy steps, tabulating the results from day to day. When the computations become too laborious the writer completes or extends the table himself. Finally when the pupils arrive at the well-known constant, it is a revelation to them; it is no longer a matter of faith with them but real knowledge absolutely independent of teacher and text-book; and the writer cannot help but believe that the number 3.1416 means vastly more to them than it ever meant to them before.

IRON IN WATER.

A half part per million of iron in water is detectable by taste, and more than four or five parts make a water unpalatable. In some mineral springs iron is the constituent which imparts a medicinal value to the water, but ordinarily it is undesirable. More than 2.5 parts per million in water used for laundering makes a stain on clothes. Iron must be removed from water from which ice is made or a cloudy, discolored product will result. An iron content of over two or three parts per million in water used in the manufacture of paper will stain the paper. Iron is harmful in water used for steaming, for it is in equilibrium with acids which inside the boiler become dissociated, with the result that the free acids corrode the boiler plates; but the amount of iron carried in solution by most waters is so small that the damage it does to steam boilers generally amounts to little. Waters having high iron content have in some places caused an immense amount of trouble and expense when used as city supplies, for they favor the growth of crenothrix to such a degree that the water pipes become clogged with the iron sheaths of the organism. The removal of iron from water is sometimes easy and sometimes very difficult.

THE DEFINITION IN GEOMETRY.[1]

By T. M. Smith,
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A critical examination of current texts in geometry reveals a variety of notions about the axioms, the postulates, and the assumptions, as well as the contents of Book I. This observation would seem to indicate that a careful study of these phases of the subject should receive attention.

When we consider the great expanse of territory addressed by the author of a school text, we may readily concede that he should not be responsible if the list of originals does not suit every locality into which the book happens to go. He cannot be expected to supply supplementary work for pupils of widely divergent interests which, by the nature of productive industries in different parts of the country, are as far apart as some of the localities themselves. Certainly here the instructor has a responsible duty in collecting or having his pupils collect original applied problems of local interest and application. But when we turn to the proved proposition, axiom, and definitions, no such diversity of demands upon the author is apparent. Hence it would seem that some sort of united effort should be made to reduce this modern "confusion of tongues" to a minimum.

How often do we read in current texts that "an axiom is a self-evident truth," while located due south of this statement is a list of facts purporting to be self-evident, but which may be demonstrated or derived from other facts of a genuine axiomatic nature.

Again, how clearly was pointed out to us, as we conned our first lessons in elementary physics, the important fact that a "great gulf" is fixed between zero and absolute zero; while in geometry where we are supposed to teach the art of thinking clearly and reasoning concisely, we often draw no dividing line between relatively self-evident and absolutely self-evident truths; nor is our course more commendable when, as Collins points out, we permit a class to call the statement that " 'Two geometric figures are equal or congruent if they can be made to coincide exactly,' a self-evident truth, when it is at best a definition of our notion of the terms equal or congruence."

[1]Read before the Ohio Association of Science and Mathematics Teachers, Ohio State University, Columbus, Ohio, December 28, 1910.

This is no religious question of infinite verities about which one expert's opinions may well be balanced by observations of another equally conscientious student of man's future destiny. But on the other hand it is a very human question of finite fact, having to do with the training of boys and girls to think to some purpose; and being such, it is essential to put first things first, and see that each is properly labeled.

The whole difficulty in the present-day presentation of secondary mathematics is a pedagogical one; and therefore the geometry teacher must be a sort of pedagogical Moses to lead those who may have been compelled to make bricks without straw, into a land of educational promise. The high school pupil is required to prove that "through a given point but one perpendicular can be drawn to a given line," a statement whose truth is just as evident to him as any one of the so-called axioms. The inconsistency is more apparent if we recall that just a few days later the pupil is tacitly requested to take for granted the fact that an angle has only one bisector. As far as consistency is concerned, one may equally as well require nine divided by three to be performed by the method of long division. However, I am not contending for proofs or their omission but for uniform consistency. Let us call things by their right names; and when an assumption is made let us be honest about it and call it such. Let the pupil understand that so-called self-evidence is not the Euclidian test for an axiom, but that it is an agreement as to fundamental, basic facts upon which to rear the logical sequence of theorems.

It is this subtle inconsistency upon the part of geometry teachers that gives rise to the oft-heard expressions, "Why, any fool can see that," and "I don't see any sense in such stuff;" statements which force the usual sermon on the value of mental training, end-points in culture, and the wonderful effect the study of geometry has had upon the lives of such famous historical characters as Napoleon, Washington, and Lincoln.

You will not wrongly understand me to be in favor of splitting hairs with the pupil on this subject, yet for the sake of the dignity of geometry as a secondary school subject on the one hand, and the pupils' welfare on the other, I am certain the time has come to eliminate these unnecessary evils.

Further evidence of the need of reform is found in the recent prophecy that "geometry must go out by the door Greek has already passed through but left ajar." The defects just pointed out are more or less superficial and are being gradually righted by makers of text-books.

The striking dissimilarity in the wording of fundamental definitions is wholly out of accord with a subject over two thousand years old. In my opinion there is but one other anomalous condition in the field of secondary mathematics comparable to it in mischievousness, and that is the promiscuous aggregation of algebraic symbols. Fortunately, the Central Association of Science and Mathematics Teachers is backing a movement to secure uniformity of usage in algebraic symbols at the present time, and it seems to me that some association might well take up the cognate problem of uniform definitions in geometry.

I am aware that at first thought a slight difference in the wording of definitions seems harmless; but a closer inspection reveals a decidedly different sequence of propositions. As an illustration, consider some of the various ways of defining parallels. If we hold with Dr. Johnson that parallels are lines that have the same direction and maintain always the same distance, we may readily say that the various pairs of corresponding and alternate angles formed by a transversal of such lines are equal by inspection; since the term direction is the essential element of the definition, and if a given line has a certain direction it can make but one set of angular magnitudes with a second direction, whether this second direction be represented by one or by more than one line.

If we agree that parallels are lines which cannot meet in finite space, we must supply rigid proofs for a number of theorems that show the equality of the above-mentioned pairs of angles. Notwithstanding this fact, the second definition is preferred on good authority, owing to the difficulty of assigning a concrete value to the term direction. It is used ambiguously, so those who are opposed to it say; but again an inconsistency creeps in, for while "direction" must be eliminated, owing to a double use of the term (since a line may have two directions if referred to any one of its internal points, and but one if referred to an extremity as in the case of the ray or half line), yet we use "adjacent" in two ways, and the

term "vertex" may mean any one of the three angular points of a triangle.

It is one thing to use terms because reputed authorities have arbitrarily decided that we should do so, and quite another to use them because they actually produce desirable results when used in the class room. Throwing aside all semblance of quibbling, the pupil knows what we mean when we say "a line may be generated by a moving point;" and he also knows what we mean when we say "direction is that which controls the generation." While it is impossible to say what electricity really is, yet we all know some very concrete results of its use, and the case is not otherwise with the term "direction." In the mind of the pupil it is inseparably linked with the notion of straight lines, and we need not reject it any more than we should reject electricity. It is amusing, to say the least, to see an author using "left to left" and "right to right" in a mad endeavor to avoid the term "direction," and in a footnote on the same page have him speak of "similarly directed lines."

The position of those who defend the lack of uniformly worded definitions in geometry becomes untenable when we consider the geometric increment to the definition. Here for the first time in the pupil's experience it becomes more than a defining process; not only does it separate the object in mind from all other concepts in the universe, but it also takes the added nature of substantial authority in proving theorems, and as such takes its place beside the axiom or assumption as an absolute fact, back of which we agree not to look. Since the term is to be regarded as a fixed point in the geometric compass, and its authority is to be unimpeachable, there must be no "confusion of tongues" in its expression.

The world-wide movement, now well under way, to improve the quality of geometry teaching is causing the most conscientious study and thorough examination of the foundation of mathematics on the pedagogical side.

It has been said quite recently that "the most significant single feature requiring attention is the teacher. What we need is not better mathematicians but better teachers." There can be no doubt about the fact that secondary school teachers need an awakening in the direction of a more thorough and intimate knowledge of the personal needs of the pupil. To

know geometry is good, but to know the child mind is imperative.

To learn as definitely as may be the exact content of the pupil's mind, and to use this knowledge as a foundation upon which to rear our educational superstructure, has long been a recognized principle of teaching. But wide as has been its heralding, and insistently as have educators proclaimed it as the fundamental of fundamentals, we even to-day find it the least used and most abused axiom in the realm of pedagogy. How often are complex notions slurred over by vague definitions, and half-true statements allowed to disgrace the pages of an otherwise teachable text. And how often do we teachers permit these slurred-over notions to remain slurred over, allowing them to be used day after day by the pupil, who with implicit faith in the teacher and a reverence for the text-book akin to awe, blunders blindly on.

Is it any wonder that the first impressions of geometry upon the somewhat satiated mind of the secondary school boy or girl is that the whole thing is bosh and a sheer waste of time? And very often, when we consider the manner in which geometry is served up these days the judgment is correct. Moreover, it is prima-facie evidence that once aroused by fair means or foul, the boy or girl passing such a concise, accurate, and fundamental judgment is capable of starting with an hypothesis and arriving with amazing dexterity at the correct conclusion.

The teacher must choose the book that meets his own personal views of orthodox scientific truth, and reject all others. With this new and very complex problem to be solved it may readily be acknowledged that the teacher is the most significant single feature requiring attention.

What with personal views, mathematical monographs, and the reasonable demands of his pupils to be squarely dealt with, the teacher certainly has not the least of his professional duties to perform when he chooses a text; and having considered all phases of the question he decides and sighs with relief. But the new text is not to be thought of as a panacea; for there yet remain pedagogical errors to be corrected, and statements, not germane to the thought, abound in spite of the pains taken to select the best book on the market. Now it becomes apparent that the last word in text-book making has not been spoken for this generation,

nor will it be until we teachers have a more thorough understanding of the habits, content, and working of the pupils' mind and have passed the good news along to the bookmakers so insistently that they dare not deny our demands.

If this forces a less commercial and more pedagogical book, addressed to sections rather than to the whole country, then so be it. Anything for the good of the pupil should be the motto of the twentieth century teacher.

There is a widely heralded modern proverb which declares that the entire school system should revolve about and center in the pupil; but the very fact of its present widespread popularity is to be understood as meaning that no such Utopia exists at the present time. Moreover, the paramount duty of every teacher to-day ought to be to make this maxim true. It is time to wake up and meet the pupil more than half way, and having found the pupil's vantage point, lead him out of darkness into light.

Now if I have been dealing in generalities more than is desirable, let me lower my sights and ask you, if you are a teacher, to take the trouble to find out how many or perhaps how few of your geometry pupils have a definite, workable notion of the definition. If you are discouraged by the experiment, try it on your fellow teachers. While I do not know either your pupils or your teachers personally, my guess is that, judged by a working standard, neither pupil nor teacher will satisfy you.

Just ask the bright boy right in the midst of a demonstration how he knows that statement he has just made is true. If not too badly nonplussed he may answer correctly and say, "By definition." But ask how he knows that to be true. He will possibly say, "The book said so." And now, fellow teachers, is your chance; ply him with questions regarding the book, and suggest that he would probably believe 2 and 2 make 5 if he but saw it in a text-book. Then will he wake up, and not only will this be so, but about twenty other young Americans will all be awake at the same time.

After hearing all each one has to say, and after you have learned that "definition means to define," and this splendid definition of a definition has been illustrated by the remarkable statement that a horse is an animal with four legs, begin with any definition in the book, say, the one of a triangle, and have everyone in the class but yourself repeat it

verbatim. Then dissect it. Follow this with the book definition of a quadrilateral; have the class repeat it and dissect it. Compare the two definitions; contrast them; let the class see wherein they are alike, and wherein they are different. Now, the very fact that the boy is awake, and that everybody else is awake, will cause some member of the class to rise to the situation and state that a definition is a statement of a set of conditions to which a convenient name has been given.

At this period, having properly praised the discoverer and illustrated his reply by a number of the most familiar definitions in the book, it will be time to seek the origin of the definition. This will necessarily require more than one recitation period, and will force a consideration of axioms and postulates. If you are well supplied with supplementary texts, you will be able to put a sufficient number of copies into the hands of the class for comparison. Just why some books give a list of assumptions, while others call them axioms and postulates, will prove of great interest to them; and right here let me state that the pupils are in great danger of learning in a manner not easy to forget, that some things are just as self-evident as the so-called axiom and the teacher's chance of a a lifetime to beget a true notion of the foundations of geometry has arrived.

Just to keep up the interest and to emphasize the foregoing, have the class hunt up the definition of circle, and let everybody but the teacher read what he finds. It doesn't really matter what he finds; the vital thing is that everyone is awake. One boy recognizes a familiar friend in the statement that "a circle is a portion of a plane bounded by a closed curve every point of which is equally distant from a point within called the center." Another finds a stranger and proceeds to introduce to the class the statement that "a circle is a closed curve every point of which is equally distant from a central point in the plane." A third leaves the class wondering what next, having read that "a circle is composed of both a portion of a plane and the closed curve that bounds it."

Here, fellow teachers, are three distinctly different definitions of a circle, and all within the pages of books labeled geometry. And the startling thing is not that they are worded differently, but that they are fundamentally different. Get an expression of opinion from the class on the merits

of these definitions. If you have not tried it, you may be surprised at the readiness with which the pupils grasp the essential nature of the definition. Just a little steering will cause them to conclude that the definition is an agreement, made by persons interested in the subject, concerning a certain set of conditions which shall be called by a certain name, and the statement of which must be so carefully worded as to shut out all other ideas in the universe.

Let them understand also that they themselves have both the ability and the right to make agreements, provided they stand willing to take all consequences of the agreement. This of course presupposes the teacher to be guiding them intelligently while they form this judgment.

In the succeeding demonstrations see to it that the pupils state the nature and content of the definition. For variety call their attention to the old definition of a trapezoid, extant in the seventies, namely, a quadrilateral having either one or two pairs of parallel sides; thus effectually distinguishing it from the parallelogram which must have two pairs of parallel sides. Some such treatment will tend to destroy the prevalent book worship, and to place the definition where it belongs, on an equal footing with the axiom as authority. But greater than either of these results will be the fact that the pupil has been aroused to a notion of his own ability to think accurately and definitely to some purpose. Again, let me say that, in my judgment, the time for definite action has arrived. Let a committee, consisting of men of unquestioned scholarship and approved class room experience, be appointed to draft a code of sane, sensible, sound, and scientifically-stated definitions for use in teaching geometry, and let every effort be made to incorporate them into every text-book on the subject.

Time was when it was thought impossible to have uniform examinations for Ohio teachers, but, thanks to progress, that time has passed, and the day is coming when the geometry definition will come into its own.

THE TEACHING OF ELEMENTARY CHEMISTRY.

By Robert H. Bradbury,
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1. Complexity of the Problem.

Chemical science is only about a century and a quarter old. As a special branch of knowledge, with its own objects and methods, it began with Lavoisier, who also wrote the first systematic text-book on the subject. The use of the laboratory as an aid in instruction dates only from the establishment of Liebig's laboratory at Giessen in 1824. The high school laboratory is a recent phenomenon. It began only about thirty years ago, and even at present laboratories are far from universal, while in many schools the large size of the classes, the shortness of the laboratory period, the lack of all efficient laboratory assistance and the necessity of working up to a formal written examination throw grave difficulties in the way of the proper development of the work.

The high school treatment of chemistry is still in its formative stage and this is especially true of the laboratory treatment, which is the more recent. The course in the class room is prevented from taking any final definite shape by the rapid growth of the sciences. This growth perpetually produces new subject-matter which tends to displace the old. Electro-chemical conceptions which were hardly represented in the text-books a decade ago, now dominate the whole treatment of large sections of the course. Colloid chemistry and radio-chemistry have hardly penetrated into the texts as yet, but they are handled in some way or other by all high-school teachers of chemistry. The practical applications of the science demand an increasing amount of attention.

So far as the experimental work is concerned, the whole matter of high school laboratory instruction is so new that no sort of general agreement has been reached with regard to the most advantageous way of handling it. Whether the work should be all quantitative, or all qualitative, or partly the one and partly the other are disputed questions. The fact that a qualitative exercise is hardly worth the time it takes, unless it is related, in some very definite way, to the general points of view of the science, seems to be scarcely appreciated as yet by the authors of text-books. The constant influx of new matter, both into the laboratory and class room, tends almost irresistibly to force the

teacher into a kind of episodic treatment. He is obliged constantly to combat the tendency to allow his course to degenerate into a series of interesting but unrelated discussions of special topics, while the logical connecting structure, which has produced all these developments, just as a tree produces its fruit, is slighted.

The time devoted to chemical science in the high school averages about five hours a week for a school year of forty weeks. Half of this time is spent in the laboratory. It is plain that this scanty allowance bears no relation to the educational value of the science, nor to its practical importance to the student. The time might be doubled with advantage by extending the course through two years, but it is difficult to see where the additional hours are to come from, and our present problem is to do the best we can with the time we have.

2. The Text-Book.

One of the invariable features of the text-books of our science has been for many years the preference exhibited for the non-metals as the subject-matter of the early part of the work. This is most noticeable in Hofmann's classical "Moderne Chemie," practically the whole of which is devoted to the non-metals and to the theory, the metals being scarcely referred to. in Friedrich Wöhler's excellent "Grundriss der Unorganischen Chemie," the first fifty pages are devoted to general theoretical matters, and in the succeeding hundred pages the non-metals and their compounds are discussed. The balance of the book (two hundred pages) is devoted to the metals which are dealt with in a compact, precise, and altogether masterly way. The difference in the importance attached to the metals by these two great chemists is most interesting.

The modern text-book authors have followed Wöhler rather than Hofmann. That is, they take up the non-metals first and use them as the raw material from which to evolve most of the important general principles of the science, while the metals are handled mainly in the second half of the book. There are, however, some important departures from Wöhler's order, most of which appear to be the result, first, of a desire to acquaint the student with at least one metal in the early portion of the work, and, second, of an attempt to arrange the order of topics with reference to materials more or less familiar to the student. This second principle of arrangement is a most important one, since

it is really the basis of all first-rate scientific exposition, and the current type of text does not in my opinion allow sufficient weight to it.

3. The Order of Topics.

Anyone who will attentively examine the chief texts in the field will be surprised at the sameness of the order of topics. It may be said that, broadly speaking, water, air, salt, and the periodic law furnish the skeleton of the conventional book.

The book begins with a general chapter, dealing with the scope of the science with physical and chemical change, with mixture compound, element solution, combination decomposition, and so on. It is plain that the student cannot possibly understand these generalizations until he has had at least one specific instance of each.

The authors meet this difficulty by intercalating illustrative experiments, and these are nearly the same in all the books—salt water for solution, iron and sulphur for combination, mercuric oxide for decomposition, etc. An alternative method, and, one might well think, a better one, would be to begin directly with the descriptive chemistry and to handle the abstract general matters as specific examples occur naturally in the course of the work. Why begin to generalize before the student is familiar with the facts which at once necessitate the generalization, render it intelligible, and supply the material for it?

The descriptive matter now begins with chapters devoted to oxygen, hydrogen, and water. Practically all the books introduce the stochiometric laws, symbols, equations, and the atomic and molecular theory at this stage. The use of water for the introduction of these generalizations began, I believe, with Hofmann.

4. Avogadro's Hypothesis.

Salt, then, serves to introduce chlorine and the atmosphere to introduce nitrogen and its compounds, after which the beginner equipped with some knowledge of hydrochloric acid, ammonia, nitrous oxide, nitric oxide, etc., is considered ready to attack his *bête noire,* Avogadro's hypothesis. In fact, the course is arranged up to this point with the object of reaching Avogadro's hypothesis as rapidly as possible, so as to permit the use of molecular formulæ. (Compare Alexander Smith, "The Teaching of Chemistry," p. 54).

The universal trouble which beginners have with Avogadro's hypothesis is a curious phenomenon. In itself, the subject is

not as difficult as some propositions in geometry which the same students handle with ease. The difficulty is often due to the introduction of the subject before a sufficient foundation has been laid for it. Among the conceptions preliminary to Avogadro's hypothesis are those of gas, homeogeneous substance, element, compound, mixture, atomic and molecular weight. These things are novel and difficult. They need to be treated in a practical and inductive, rather than in a theoretical and dogmatic way. The last six ideas can hardly be imparted successfully without much laboratory work with *solids,* especially sulphur and the familiar metals.

When these seven conceptions have been deliberately worked out, Avogadro's rule may be given, simply in *grams* and *liters,* and enforced by illustrative problems. The molecular hypothetical presentation forms the rational conclusion of the subject. I have satisfied myself that the difficulties which beset the subject of Avogadro's hypothesis disappear if this course is followed. The only disadvantage is that the introduction of *molecular* formulæ is somewhat postponed, but this is not as serious as it looks at first sight. At present we have decisive evidence for the molecular weights of gases and dissolved substances only. The innumerable formulæ of liquids and solids which we constantly employ are not truly molecular. HgO, FeS, NaCl, Na_2SO_4, and H_2O (liquid) are a few out of hundreds of instances with which our text-books bristle. We are practically without evidence with respect to the molecular weights of these substances, and the formulæ are merely the simplest expression of the percentage composition. Of course this does not interfere in the least with their use in equation-writing or in solving problems.

For this reason, it seems to me that the importance of the early introduction of molecular formulæ has been greatly exaggerated. For instance, there is little consistency in the present state of our knowledge in forcing the student to write—

$$2\,HgO = 2\,Hg + O_2, \text{ instead of}$$

$$HgO = Hg + O.$$

The first equation is no more a correct representation of the mechanism of the change than the second. When the conception of molecular weight becomes applicable to solids we may be obliged to use a still more complex equation, *e. g.*:

$$Hg_{10}\,O_{10} = 10Hg + 5O_2$$

but, at present, the simplest equation is the easiest for the beginner to handle, and also the most scientific, since it keeps within the limits of our knowledge of the matter. Obviously the same remarks apply to similar cases like—

$$KClO_3 = KCl + 3O.$$

5. Residual Topics.

The next subject is Van't Hoff's extension of Avogadro's hypothesis to solution, which leads up to ionization and to the completion of the topic of acids, bases, and salts.

At this point—roughly speaking the middle of the book—a certain divergence of opinion becomes apparent. According to the manner in which the latter half of the work is arranged, the texts can be divided into three classes:

1. Those in which there is a chapter on the periodic law—somewhere near the middle of the book, the periodic classification being followed after this point.
2. Those in which the periodic classification is followed through the latter half of the book, but the formal discussion of the law itself is postponed to the end.
3. Those which make no attempt to follow the periodic classification but discuss the law itself at the end in the light of all the knowledge which the student has gathered.

Excellent texts have been written according to all three of these plans, but the teacher who tries all three methods will conclude that the third offers the fewest disadvantages. The first is of course the most systematic, but it is almost unworkable with average classes. In a subject to which only about two hours a week in the class room can be given, it is impossible in half a year to bring students to a stage at which they are ready to grasp the periodic generalization. If the teacher can reach this point with his classes at the end of the year he has done well and has every reason to be gratified with the result of his labors.

As for the second plan, the method of giving the facts first, and then erecting the generalization upon them, is usually by far the best approach to any abstract topic. But the periodic law is an exception. The material summed up in it is too extensive for the student to retain it until the time arrives for the setting up of the generalization. To classify tin with carbon, gold with sodium, manganese with chlorine, and to lay stress on non-existent oxides in the hope that, when the time comes to study

the periodic law, the student will reap some advantage, is little better than a waste of time. It is far better to classify the elements in the simplest and most natural way and to add whatever modifications are necessary, from the periodic viewpoint, in the chapter devoted to that subject. If the law is then given a candid treatment, which calls attention not only to its dramatic achievements but also to its numerous puzzling defects, the subject will arouse the keenest interest of the students and will serve, at the same time, as a valuable review of a large portion of the material of the course.

6. Summary.

It may be well to point out that we are making the assumption that the arrangement of the work is the same as that of the text employed, so that it is unnecessary to discuss the two separately. Thus far, we have devoted ourselves to what may be called, in no disparaging sense, the *conventional* type of book. At this stage it will be useful to sum up the results of our examination.

(*a*) The conventional text is constructed with the object of teaching the student the facts and results of chemical science, so far as possible during the very limited time available. The knowledge which it seeks to give is of the kind which can readily be tested by a written examination.

(*b*) As an essential feature of this program the stress is laid wholly upon the *subject-matter,* while the *method* of the science is hardly noticed at all. Thus, a student who has mastered the treatment of the atmosphere in the current type of text will have a rather complete knowledge of the properties of the different gaseous constituents and the proportions in which they are present. With respect to the way in which all this knowledge has been acquired, or to the way in which he might go to work to investigate the matter for himself, he will have only the haziest ideas. If his knowledge is called into question, he will probably be unable to defend it, except by reference to the books where the statements are to be found. The conventional text is almost wholly dogmatic—as distinguished from inductive—in its presentation. Everything is communicated—hardly anything is proved. Little space is given to the historical side of the science, for teaching chemistry along historical lines is almost the same thing as teaching it inductively. In both plans, the effort is to show how the generalizations arise out of the facts, and both

will, in at least nine cases out of ten, lead to the same order of presentation of a topic.

(*c*) Another aspect of dogmatic presentation is that the orderly development of the student's ideas, which is really the whole object of the work, is relegated to the background as a minor matter, the main aim being to achieve a compact, accurate, systematic statement of the facts and principles the student is to learn. In this the shadow cast by the impending examination is plain.

The desire for compactness is probably responsible for the way in which substances and processes totally strange to the student are employed at the beginning of the work. In the introductory chapter of his text the student usually finds himself confronted with sulphuric, nitric, and hydrochloric acids, with mercuric oxide, potassium chlorate, silver nitrate, sodium and carbon disulphide, with solution, crystallization, and electrolysis.

I venture to think that there has been too much of this sort of thing. It is, of course, an important part of our business to enlarge the student's knowledge of the elements and their compounds, but the enlarging should be done in a logical way. The introduction of an unfamiliar substance before the time has come for its full discussion is a serious evil, and it is an evil which can usually be avoided by a little care in the arrangement of the work.

7. The Heuristic Method.

We may permit ourselves, then, to indulge in the paradox that the current type of chemical text is essentially a *popularized* form of chemical science. It is popular in the sense that its leading aim is to achieve a general survey of the results of the science, without much reference to the process by which those results are obtained. Strictly scientific literature contains not only certain results of investigation, but also the rigorous evidence which will convince all normal men, who will take the trouble to analyze it, that those results are correct.

The *heuristic* method—which under the energetic advocacy of Prof. Armstrong has had a profound effect upon the teaching of our science in England—abandons at the start all idea of making a systematic survey of the subject. The stress is laid, not upon the results, but upon the method of the science, and the student is put in the attitude of an investigator from the first. The early part of the work is confined to familiar materials

such as sulphur and the common metals, air, water, salt, and pyrite. The facts obtained by simple experiments are gradually organized, without any effort to hurry the development of the generalizations.

There is no doubt that the advocates of the heuristic method have grasped an educational factor of great importance. The objection often made, that it is useless to train students in research because so few of them will become investigators, is no answer to their contention. Research is simply the solving of problems by observation and experiment, and every man whose function requires something more than mere routine work is of necessity continually engaged in investigation. The problem, for instance, of reducing the cost of a manufacturing process is fundamentally scientific and is to be solved by methods very similar to those which enable a student to ascertain whether copper and sulphur do or do not unite in fixed proportions by weight. And there can be no question that the ability to attack a problem aggressively by experiment, and to think accurately in interpreting the results, is far more valuable as a preparation for life than even the most encyclopediac knowledge of facts.

Much damage has been done the heuristic method by the extravagant claims of some of its friends. Consider, for instance, this passage from Arendt[1]: "Die Schüler haben die den chemischen Erscheinungen zugrunde liegenden Ursachen selbst auszufinden und die zum Ziele führenden Versuche und die Art ihrer Ausführung auszudenken. Der Versuch werde stets zur erforschung einer Ursache veranstaltet, die Theorie werde aus der Beobachtung entwickelt, und zwar müssen die Schüler die allgemeinen Begriffe und Regeln selbst ableiten."

The services which Prof. Arendt has rendered to chemical education are great, but this particular passage is little better than pure nonsense. A course in which the student was required to recreate the science—experiments, theory, and general principles—for himself would be wholly unworkable, for it assumes the possession of superhuman intelligence. The great investigators have won their imperishable renown by doing for small portions of the science exactly what Arendt would require each student to do for the whole subject. Supposing that the start was made, in the simplest possible manner, by heating sulphur with familiar metals, it is doubtful whether the student would come

[1]Compare Zeitsche für Phys. u Chem. Unterricht, Vol. 23, p. 192.

unassisted to the conclusion that the substances supplied to him were elements and that he was dealing with cases of combination.

COMPROMISE.

It will not answer simply to assume that the student must find out everything for himself, for this would forbid all progress. How much he is to find out and how much is to be communicated to him must be decided by careful consideration of each topic. For instance the proof that copper and sulphur are elements is clearly beyond the powers, not only of the beginner, but also of the advanced student. But, *assuming* that copper and sulphur are elements, the proof that, when heated together they combine in definite proportions by weight forms an exercise which the beginner will work out with surprising enthusiasm and exactness.

The intelligent practical limitation of the heuristic method forms a complex problem which has been most successfully solved, so far as I know, by Otto Ohmann of the Dorotheenstädtischen Realgymnasium at Berlin.

In handling the atmosphere, for instance, the usual course is to describe oxygen, to describe nitrogen, to tell the student that these two gases in certain proportions make up the chief part of the air, which, however, contains smaller quantities of other substances, and so on.

Before attacking the atmosphere, Ohmann's book[2] gives the student an opportunity—from some work with sulphur, with the common metals and some mineral sulphides—to form the conceptions of element, compound, and mixture. The chemical study of the air is then begun by investigating the effect of heating metals in it, at first qualitatively and then with reference to increase in weight. By heating a folded piece of sheet copper and noting the absence of action in the interior, it is proved that air as well as heat is concerned. The familiar experiment in which iron powder hanging to a magnet is heated in a bell-jar over water is next applied to prove that only a portion of the air disappears, and this is followed by the passing of a measured volume of air through a tube containing heated copper, the residual gas being collected over water. Thus *nitrogen* is reached before oxygen. After the properties of nitrogen have been briefly studied, oxygen is obtained by heating mercuric oxide. This is introduced not by name, but as a red powder which bears

[2]Leitfaden der Chemie 5th Aufl. (1910).

the same relation to mercury as the black powder obtained by heating copper in the air does to copper. The student's knowledge of oxygen is then enlarged with the aid of a cylinder of the compressed gas.

Other topics are handled similarly. It is plain that a student who studies chemistry in this manner will not only know something about it, but will also know *how* he knows it. He will have some idea of the way in which the science goes to work to get its subject-matter, which is at least as important to the student as that subject-matter itself. It is also clear that a subject handled in this way is taken up essentially in the historical order. This is more than a mere coincidence. As Goethe remarks, in his brief but exhaustive way, "Die Geschichte der Wissenschaft is die Wissenschaft selbst."

HANDBOOK OF ALASKA.

Progress of the Mineral Industry of Territory for 1910 as Reported by the United States Geological Survey.

What may be termed the United States Geological Survey's "handbook of Alaska" has just been issued in its seventh volume, summarizing for the year 1910 the conditions of the mining industry in our far northwest territory and the most important results accomplished by the investigations of its mineral wealth. The volume consists of thirteen chapters, which are also published as separate pamphlets.

The separate reports are as follows:

The Mining Industry in 1910, by A. H. Brooks, 22 pages.

Geologic Features of Alaskan Metalliferous Lodes, by A. H. Brooks, 51 pages.

Mining in Southeastern Alaska, by Adolph Knopf, 9 pages.

The Eagle River Region, by Adolph Knopf, 9 pages.

The Upper Susitna and Chistochina Districts, by F. H. Moffit, 16 pages.

Preliminary Report on a Detailed Survey of Part of the Matanuska Coal Fields, by G. C. Martin, 11 pages.

A Reconnaissance of the Willow Creek Gold Region, by F. J. Katz, 14 pages.

Placer Mining in the Yukon-Tanana Region, by C. E. Ellsworth and G. L. Parker, 20 pages.

Water Supply of the Yukon-Tanana Region, 1910, by C. E. Ellsworth and G. L. Parker, 45 pages.

Mineral Resources of the Bonnifield Region, by S. R. Capps, 18 pages.

Gold Placer Mining Developments in the Innoko-Iditarod Region, by A. G. Maddren, 35 pages.

The Shungnak Region, Kobuk Valley, by P. S. Smith and H. M. Eakin, 35 pages.

The Squirrel River Placers, by P. S. Smith, 13 pages.

Most of the reports are illustrated by sketch maps. Copies of any of the chapters may be had on application to the Director of the United States Geological Survey, Washington, D. C.

CONTOUR MAP MAKING.

BY LEONARD RIGHTER,
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Since most of the maps now prepared by the United States Government are contour maps, it becomes necessary in the public school to teach the idea of contour lines and intervals and what they show. This can easily be done by the use of a plaster-of-paris model as many most excellent manuals indicate. The author, however, believes that the most correct and lasting impressions can be gained by out-of-door work on a real land surface. Nearly every school is within reach of a suitable land surface either in city park or country hillside. The great difficulty would seem to be the lack of suitable instruments with which to obtain the various elevations. The object of this article is to present a simple and inexpensive set of instruments for the above-mentioned purpose.

The most important instrument is the level. If the school could afford a level from which the elevation angles could be read it might find considerable use in the geometry and trigonometry classes, but in contour work the angles might complicate matters too much.

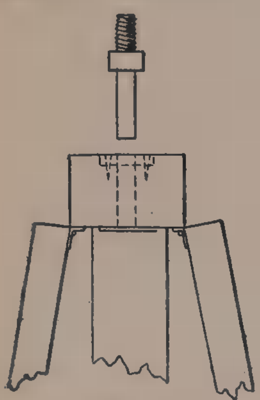

Fig. 1

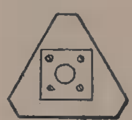

Fig. 2

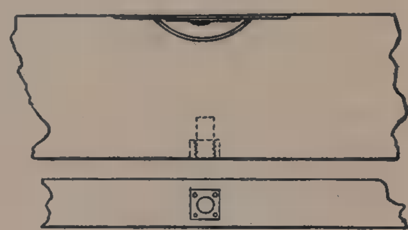

Fig. 4

Fig. 3

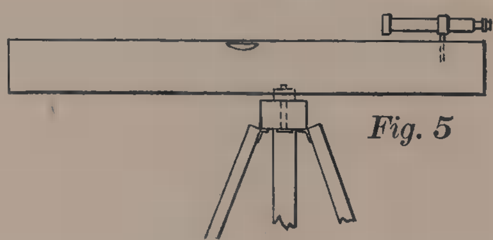

Fig. 5

For the work suggested a carpenter's level, with sights at each end and mounted on a tripod, is very effective. The tripod is made by selecting a triangular block of birch 3 inches on a side and 1½ inches thick (Fig. 2). On the top side a brass plate is set into the surface. Through this

plate and the block is drilled a 3/8 inch hole. The legs are made of straight pine 1½ inches by 7/8 inch at the top, tapering to 1 inch by 7/8 inch at the bottom. They may be cut about four feet, four inches long. These are hinged to the triangular block by tight action hinges (Fig. 1).

Small notched pieces of brass (Fig. 3) screwed to the ends of the carpenter's level make good sights; or, if the laboratory possesses a small telescope this may be mounted on the level as shown in Fig. 5. Care must be taken, of course, to have the axis of the telescope or the line through the sights perfectly parallel with the level. On the under side of the level a thick piece of brass is set flush with the surface (Fig. 4). This has a hole threaded to receive the post that fits into the hole in the tripod block. If this latter hole has been made to fit the post exactly, the level can be turned about in any direction and there will be very little undesirable movement.

A pole 10 feet or 12 feet long, marked off in feet and tenths of a foot, is needed, and a common tape line serves the amateur surveyor very well in measuring distances if a chain or steel tape is not available.

In the field a standard point of origin must be selected and its location and elevation determined. From this lay off a north and south axis and an east and west axis. These lines serve as a basis from which the whole region may be laid off in a checker-board fashion. The elevations at the corners of the squares may then be determined by sighting the level on the leveling rod and reading the number marked thereon in line with the sights or cross-hairs of the telescope. Having adopted a suitable scale, these numbers, after allowing for the height of the level, can be transferred directly to a sheet of cross-section paper. The contour lines may then be drawn.

Such a map made by actual experience in the field fixes easily and permanently the ideas of contour lines and intervals and makes clear how such lines show elevation, shape of land surface, and amount of slope.

CHAPTERS IN THE HISTORY OF AMERICAN BOTANY.

JOHN M. COULTER,
University of Chicago.

FORTY YEARS OF PLANT MORPHOLOGY. I. (1870-90).

The history of plant morphology in the United States may be written as a history of botanists or as a history of the subject. To estimate the influence of various botanists upon the progress of botany is not only difficult, but also often invidious; but to trace the development of the subject is comparatively simple. It is useful to have in mind the different stages of this development, for it enables one to assign botanists and botanical teaching to their appropriate periods. It must be recognized, of course, that all the stages of development not only occur in chronological succession, but also are contemporary in the persons of different botanists and teachers of botany. It must be remembered, also, that progress does not mean abandonment of the old, but enlargement and enrichment of the old. The "new botany," therefore, which is welcomed from time to time, is not a new individual, but the same individual better developed and therefore more efficient. The progress of the subject may be likened to a tree, rooted and grounded in all that the past has revealed, but stretching out its branches and ever renewed foliage to the air and the sunshine, and taking into its life the forces of to-day.

It is very convenient to think of the progress of botany in this country by decades, for each decade has been characterized by a new point of view that became incorporated in the science and in teaching. The decade ushered in by 1850 stands for the birth of modern botany as distinct from what may be called mediæval botany. It was the decade of Hofmeister, whose studies of comparative morphology made botany an evolutionary subject. This new impulse, given in Germany, did not reach the United States in that decade, during which we still dozed along in the mediaeval stage.

The decade begun by 1860 was the decade of Darwin, that is, it included the appearance of his "Origin of Species," and what that meant to the progress of biology in general is too familiar to need repetition. In botany Hofmeister had furnished the facts, and ten years later Darwin supplied the pregnant idea. There was a sufficient reason why this sec-

ond scientific impulse did not reach the United States during the decade of its origin, for it was the decade of our Civil War, and everyone was thinking of more serious things.

The decade beginning with 1870 is the one during which the older botanists of to-day began their work, and it was dominated by Asa Gray, our most distinguished American botanist. The new movements in botany had not yet reached the United States, and during this decade the older morphology was taught, and the classification of plants was the chief subject of botanical investigation. Gray was not only a great taxonomist, but a great teacher through his books, which are models of presentation. All of us who began our botany during the 70's believed that Gray's texts contained the last word that could be said about botany, and there was accorded to the author a place of authority in his subject that must remain unique in the history of American botany. The morphology presented was that of Goethe, who proposed the doctrine of metamorphosis. Every part of a plant was referred to root, stem, or leaf; and the chief motive in teaching was to enable the student to recognize these three fundamental organs under their numerous disguises. Naturally, such work, for the most part, was restricted to seed plants, or "flowering plants," as they were called. The general impression of botany developed, therefore, was that it stood for an extensive terminology applied to organs that appeared under numerous disguises, and that these variations enabled one to give to every plant a place and a name among its fellows.

The decade introduced by 1880 witnessed the coming into the United States of the German influence. In Germany, at that time, Sachs was the preëminent teacher; and his point of view was made available to the American colleges by Bessey. Bessey's text must be held responsible for the dawn of modern botany in the United States, and from the time of its first appearance American botany has advanced with rapid strides. The outstanding features that characterized this special brand of "new botany" are as follows: The whole plant kingdom was included in a general survey, and plants were not compelled to achieve the dignity of a flower before they were worthy of study. The mature organs were studied, not only as to their superficial appearance but chiefly as to their intimate structure. Rigid definitions were established, so that all structures and tissues could be pigeon-holed. Facts were accumulated as facts without any

special thought of their interdependence in an evolutionary scheme. Among the structures studied, chief emphasis was laid upon reproductive structures, so that the "up-to-date" botany of that decade might well be spoken of as the morphology of reproductive structures.

In the use of this material for teaching, the so-called method of "types" was developed. A very few plants, fondly supposed to be "representative" and known to be common, were selected and given an exhaustive examination. Each plant was cross-questioned until questions failed; and the result was a great deal of detailed knowledge about a few plants, and very little conception of the plant kingdom as a whole. In fact, the teaching was more a training in scientific method than in botany. And when one remembers that laboratory work was new, this was not a bad start, for the method had to justify itself.

THE PURPOSE AND METHOD OF EXPERIMENTAL WORK IN PHYSICS.[1]

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The Laboratory Course.

Diverse and conflicting views have been entertained with respect to the proper function of the laboratory course in elementary physics. At the one extreme it has held a subordinate position as a loosely attached appendage to the text-book course; and, in the manner of appendages, it trailed humbly behind the work of the class room. At the other extreme it has been the dominant feature of the physics course, and as such has claimed much the greater part of the time allotted to the subject. It has been wholly qualitative, wholly quantitative, and partly both. It has been made the basis of inductive teaching, both good and bad; and it has flippantly undertaken to "verify" the generalizations of experts in experimental science.

The experiment of teaching experimental physics has been tried out along all possible lines; and the good and the bad, the better and the worse, have been evaluated with some approximation to accuracy. Differences of opinion still exist; but they

[1]Excerpt from "The Physics Teachers' Handbook," a forthcoming work by the writer, read before the Pacific Coast Association of Chemistry and Physics Teachers, July 29, 1911.

relate, for the most part, to questions of minor importance. The proper field of laboratory physics, its aims, and its methods, can now be discussed with some possibility of fairly representing a majority opinion.

The laboratory work should constitute an organic and integral part of the physics course, and should be pursued concurrently with the instruction of the class room throughout the subject. Its specific purpose is to enlarge the pupil's acquaintance with the facts of the subject at first hand. This purpose is shared on an equal footing with the experiments of the class room, performed by the teacher. The experimental facilities of the class room and the laboratory are different and mutually complementary. Neither can take the place of the other.

The relative amount of lecture table and laboratory experiments may vary considerably without detriment to the subject, for there is much common ground that may be covered by either or both together; but a well-balanced development of both is necessary for the best results. The exclusive allotment of qualitative experiments to the class room and of quantitative to the laboratory is an unwise and unnecessary restriction of the field of usefulness of each. As a general rule, the quantitative work belongs to the laboratory course; but roughly quantitative experiments are often valuable in the class room, as a basis for the preliminary discussion of quantitative laws; and, where occasion demands, they may be made to serve in the place of laboratory experiments. The special field of the lecture table experiment is in the qualitative study of phenomena which can be readily observed at a distance. By the use of the projection lantern this field can be extended to include phenomena which would otherwise require minute observation at close range. In such cases, however, as well as in others which cannot be thus adapted, the laboratory offers the best opportunity for effective work. In the laboratory the pupil *feels* the increasing pressure as he pushes a light body (as a beaker) further down in water; he *feels* that a copper rod becomes hot enough to burn his fingers while a glass rod remains cold when an end of each is held in a flame; he *sees* that an object at the bottom of a vessel appears to rise as water is poured in. Qualitative experiments such as these, and there are many of them, yield an experience which is different in kind and in value from that gathered in observing lecture table demonstrations at a distance; and on this score they are entitled to a place in the laboratory course.

As to the general character of the laboratory work, every experiment should measure up to two requirements. It should be real physics, and it should have a definite purpose and value as a part of the course. It is a waste of valuable time to spend the first days in the laboratory on pure measurement with vernier and micrometer calipers, the diagonal scale, the spherometer, etc., with no physics in sight. It is the specific purpose of the laboratory work to teach physics; and the experimental procedure should be as simple and direct as will serve the purpose. It is an educational blunder, as well as a waste of time, to introduce the use of micrometric instruments and the Jolly balance in the work on density and specific gravity, when the pupil has had no practice in the simpler methods of measuring and weighing.

The educational value of the laboratory work depends very largely upon the mental attitude which the pupil is led to assume toward it. Above all things else it should bear the stamp of sincerity. There should be no playing at discovery; and of real discovery there is none, for does it not consist in following a blazed trail. There should be no shallow pretense of "verifying" the general laws and principles of physics. The attitude of verification stultifies the intelligence; for it ignores both the quality and the quantity of the experimental evidence upon which the generalizations of science are founded, and it attaches a wholly fictitious value to the practice work of the student. The laboratory experiment is not a proof of the law, but an aid to the right understanding of it. This distinction is fundamental. For example, in the study of Boyle's law the pupil experiments with one gas only (air), at one temperature only, and with only a moderate range of pressure. With the apparatus commonly provided, the work is well done if it is not in error by more than one or two per cent. If this is accepted as an exemplification of the law, with a fair and reasonable approximation to accuracy, it is well. If it is further understood that the law has been established by similar but much more accurate work with many gases, for a much greater range of pressures, and at different temperatures, and that the law has thus been found to be only a close approximation to the truth, and that it fails even as an approximation for any gas when near a temperature and pressure at which it liquifies, it is well. Such teaching will foster a just appreciation of what science is, and a very wholesome and serviceable respect for scientific authority. But if the pupil is led to believe that all this, or any part of it, may be

assumed on the basis of his experiment, the work is a harmful perversion of scientific education.

It is of course true that the laboratory work affords a sufficient basis for important inferences and conclusions; but these are necessarily simple, and generally narrow and partial. Intellectual integrity demands that they go no further than the experimental data will warrant.

The most important and perhaps the most difficult problem concerning the laboratory work is to make effective use of it. If it has only such connection with the work of the class room as the pupil makes on his own initiative, it will have very little value indeed. Pupils well above the average in intelligence and steadiness of purpose generally fail to grasp the full significance of an experiment until the results have been subjected to a searching analysis under the guidance of the teacher; and the less capable members of the class are hopelessly incapable of deriving reasonable benefit from the work without this assistance. Acceptable results, duly recorded in a note-book, give no assurance of successful work. It is the interpretation and assimilation of results that counts, and that only.

The means by which this result can best be secured depend largely upon the size of the class, the time allotted to the laboratory work, and the predilections of the teacher. With a class of ten or less, individual instruction in the laboratory may suffice, especially with a double laboratory period. With only a single period for the work and large classes (fifteen to twenty-five), this becomes impossible. Under such conditions the only effective plan is to make the laboratory experiment the basis of a class discussion, after all members of the class have performed it. This class discussion or recitation should fit in with the text-book lesson on the topic which the experiment illustrates. On this plan, the laboratory work precedes the formal recitation. It is an obvious advantage to bring the two as close together in time as possible; and this is the principal reason for providing several sets of apparatus for each experiment, as discussed later.

As a further means of shortening the time interval between the work of the laboratory and the class room, the school program should be arranged, if possible, so that the laboratory days may be varied at will. Thus it may be found desirable to run three days of recitation, two of laboratory work, four of recitation, one of laboratory work, two of recitation, etc., according as the laboratory experiments may chance to fit in with the work of the

class room. The loss of the movable laboratory day is one of the great disadvantages of the double laboratory period, which, as a rule, must come on fixed days of the week.

In order to make the most out of the laboratory work, it must be brought into mutually helpful relation with the study of the text-book; each must be serviceable as a means of interpreting the other. The text and the experiments are different lines of approach to the same goal, namely, an understanding of physics. The two aids to the understanding will be most effective when used together. This leads to the practical rule that at least one reading of the text-book on the topic of the experiment should precede the laboratory hour; that the text-book should be brought to the laboratory, to be used at the pupil's pleasure and upon the advice of the teacher; and that the lesson of the experiment should be borne in mind as the text is further studied in preparation for the recitation.

I am not in sympathy with the view that the pupil should come to the laboratory wholly uninformed on the subject of his experiment, in order that he may weakly imitate the methods and weakly experience the pleasures of original discovery. True, the laboratory should afford valuable training in scientific methods and habits of thought, and nothing that militates against this should be tolerated; but the use of the text-book as recommended is not open to such objection. It should be remembered that the scientific investigator, in addition to his other qualifications, is skilled in the use of books. Before undertaking original work on any problem, he consults authorities to find out what is already known about it. To save time and useless labor, he begins his own investigations where his predecessors left off. The boy of to-day who is interested in wireless telegraphy or in aviation has learned this lesson without any help from his teachers; for he is a diligent reader of scientific periodicals which give up-to-date information on his hobby. Training in the effective use of scientific literature is no less a necessary part of scientific education than is training in the methods of investigation; and the former is more likely to be of use to ninety-nine out of a hundred pupils than the latter.

The principal factors which determine the details of laboratory management are the length of the laboratory period, the size of the classes, the number of sets of apparatus available for each experiment, and the number of pupils (one or more) assigned to each set.

The one important advantage of the double laboratory period (an hour and a half) is that it affords time for the experimental work of the exercise and for the preparation of a complete and final report upon it. With the judicious help of the teacher at the time of the writing, the errors of the record are reduced to a minimum; and, under the rule that notebooks are not to be taken from the laboratory, the record is free from the suspicion of dishonesty which too often attaches to work done on the outside. The double laboratory period usually carries with it the disadvantage of fixed laboratory days, the objection to which has already been noted; and each class takes a larger fraction of the teacher's time. With a single laboratory period, it is practically necessary to have the record completed on the outside; since it is out of the question to limit the course of experiments to such as can be performed and written up in so short a time. The only serious objection to this plan is that it puts temptation in the way of pupils who have access to old notebooks on the same experiments. This evil may be reduced to a negligible minimum, or it may become a serious menace to the morals of the class. It all depends on the teacher's ability to manage the situation. If it is clearly understood that the pupil's promotion will be determined by the physics stored in his head rather than in his notebook, and that the notebook is only a means to an end, not an end in itself, the temptation to dishonesty will not be very serious.

The proper size of laboratory classes has been the subject of much discussion. The view entertained by many that the number should not exceed fifteen, and would be better be ten or twelve, appears to me untenable. If the instruction based on the laboratory work is given only as individual instruction in the laboratory; if, in other words, the pupil's laboratory experience is not correlated *in the class room* with the work of the class room, then indeed a laboratory section of ten or twelve is the maximum for satisfactory results. But why conduct the work on such a plan? It is appallingly wasteful of the teacher's time and energy to discuss in full detail the significance of each experiment with the pupils individually, and it is practically impossible to do so even with classes of ten or twelve. Nor is it clear that such individual instruction is more necessary or desirable in connection with the laboratory experiments than it is with the experiments of the class room or with the illustrations and applications of physical principles in daily life.

It is the business of the elementary laboratory to afford opportunity for gaining a selected and directed experience under good working conditions. It is assumed that the pupil will endeavor to make something out of this experience at the time. Only by constant effort in this direction does the work of the laboratory become a means of intellectual growth. But suppose the pupil fails of full success in this endeavor, as he generally will. If he is one of twelve, he is entitled only to seven and one half minutes of the teacher's time in a double laboratory period, and to half that in a single period. His needs will surely be better served if he has the benefit of a class discussion in a class of twenty or more, even if he must wait a day or two for this assistance.

If the threshing out of results is made the business of the class room, as here advocated, and if the laboratory is fully in order for the work of the hour before the class assembles, an experienced teacher can give the necessary assistance to a class of twenty-four, or even thirty. Twenty-four is the preferable maximum; for, as numbers increase beyond this limit, the details of management become more exacting, and the unavoidable noise and movement of the class begin to distract the attention and to interfere rather seriously with the work. The difference between a class of twenty-four and one of thirty in this respect is much greater relatively than the mere difference in numbers.

The question whether pupils should work singly or in groups admits of two satisfactory answers. They should either work singly or in groups of two. Other conditions being equal, twice as many duplicate sets of apparatus must be provided for individual work as are required where pupils work in pairs. With most schools this consideration alone carries the decision in favor of the latter plan; and it has other merits. The old adage that two heads are better than one holds true in the laboratory as elsewhere; and it is also true that two pairs of hands are better than one in many experiments. This plan requires more tactful management than the other, especially with large classes, since a considerable amount of talking must be permitted, but this is not a difficult problem.

Working in groups of three or more is unsatisfactory, as a rule. No more than two can participate to advantage in the use of the apparatus. The others must perforce become spectators; and, in the natural working of the plan, this role will fall to the lot of those to whom it is most congenial but least beneficial.

The weaker members of the group will also depend upon the more capable to do the thinking. But worst of all, the spirit of an indifferent member of the group is apt to prove contagious.

To secure the advantage of a minimum time interval between the work of the laboratory and the class room, several duplicate sets of apparatus must be provided for each experiment. This duplication has the further important advantage of economizing time in the laboratory, by saving the repetition of oral directions. All things considered, the best plan is to provide a sufficient number of duplicate sets to accommodate the entire class on two exercises. With pupils working in pairs, in classes of twenty-four as a maximum, this would require six sets of apparatus for each experiment. Twice this number would be necessary to accommodate all on the same experiment. The advantage to be thus gained would hardly justify the added expense.

Double the regular number of sets of apparatus should be provided for experiments where individual observation is necessary and much time would be wasted in taking turn at the work; e. g., in studying the heat conductivity of rods by the sense of touch, and in the usual experiments on point image in a plane mirror, the refraction of light through plates and prisms, the study of color, etc. It is also a practical convenience to double the regular equipment for the first few experiments of the course, in order that the whole class may start together, and take the experiments in regular order from the first day. The separation of the class into two or more groups, as may be desired, will soon take place of itself, particularly where the first exercises consist of several short experiments.

With most schools an adequate equipment is a matter of several years' growth. In such cases it is better to begin by providing two or three or even four sets of apparatus for each experiment of a minimum course than to provide only one set for perhaps a considerably larger number of experiments. As years pass, the increase in the number of experiments and in the number of sets of apparatus for each should proceed simultaneously.

The importance of system, order, and general fitness of conditions to the work of the laboratory can hardly be overestimated. In such matters the teacher should set an excellent example, and he should train his class to follow it. Boys are notoriously careless and indifferent to the litter and disorder in which they may leave their temporary quarters, whether it be at the labora-

tory table or elsewhere. The instincts and habits of the cave dweller have a strong hold upon them. As a measure of self-defense, as well as in the interests of civilization, the teacher should develop in his pupils a sense of responsibility for the condition of the apparatus and table where they are at work, and especially for the condition in which these are left at the end of the hour. The first law of a well-conducted laboratory is order.

Class Room Experiments.

The class room affords opportunities for experimental work of the greatest value to the course. Without such experiments the teaching is necessarily less effective, however fully the laboratory course may be developed. For various reasons, the experiments of the class room are, as a rule, impracticable in the laboratory; and also, as a rule, they have no laboratory equivalent.

The laboratory experiment is predetermined and fixed. It follows a set of written or printed directions, from which the pupil can rarely depart with any profitable result. The class room experiment is adaptable. Where occasion demands, it can be repeated under varying conditions until the essential facts stand out clearly; and an experiment, suggested by a class discussion, can often be improvised and tried out at once to settle a question or a doubt. Skill and resourcefulness in the adaptation of experiments to fit the questions of the class add immensely to the effectiveness of the teaching; and their exercise serves as an impressive object-lesson on the methods of investigation.

The experiments of the class room are adaptable not only in their character, but in their purpose as well. They fit into the general plan of the course in a variety of ways. Most frequently they serve to introduce new topics, particularly where the laboratory experiments on a topic are quantitative. The typical procedure in such cases is as follows: (1) Qualitative class room experiments, either preceding or following an assigned reading of the text. If the reading precedes the experiments, the teacher will expect the class to take an active part in an informal discussion of them as they are performed. If the experiments precede the reading, the teacher will comment briefly upon them as they are performed, directing the attention of the class to the significant facts to be observed, and will assign the reading of the text and the discussion of the experiments for the following day. (2) The laboratory experiments on the topic, supported by further study of the text. (3) Recitation on the

text and the laboratory experiments, together with problems and applications.

As an example, let us see how this procedure applies in studying the reflection of light. Before the pupil begins the study of mirror images in the laboratory, he should have a clear conception of beams and cones of light, both diverging and converging, of regular reflection, of angles of incidence and reflection, and of the law of reflection. These ideas are readily grasped from direct observation of beams and cones of light in a fully darkened room, into which a horizontal beam of sunlight is thrown by a porte-lumiere. Chalk dust in the air (from two erasers struck together) makes the path of the light plainly visible to the entire class. The phenomena mentioned are exhibited by reflecting the beam from plane and curved mirrors. Similar experiments can be shown with the Hartl optical disk without darkening the room. It is worth while to use both methods. Having this acquaintance with the fundamental facts of reflection, the pupil is better able to work out their consequences in the laboratory study of mirror images. Following the laboratory work, the class discussion or recitation is made the occasion for a general review and summing up of the topic.

Not infrequently the experiments of the class room are given to best advantage after the laboratory work on the same topic; e. g., experiments on applied pressure (Pascal's law) after the laboratory experiments on the gravity pressure of liquids; ways of using the lever, following the laboratory exercise on moments of force; more detailed study of the transmission, absorption, and reflection of radiant energy, following the simpler laboratory work on the same topic; and similarly in the experimental study of dispersion and color, magnetism, electromagnetic induction, etc. There is no invariable order of class room and laboratory work which is best in all cases.

The experimental illustration of many topics is best conducted wholly in the class room. In such cases the experiments will be presented from day to day, coincidently with the class discussions and recitations from the text. Among the subjects which can be presented to best advantage in this way may be mentioned the greater part of dynamics (the mechanics of accelerated motion), diffusion, vapor pressure, the greater part of sound, and the whole of electrostatics.

It is clearly a misappropriation of time and energy to have the class keep a record of the lecture-table experiments. There

is valuable training in written work, when properly supervised; but there is enough of it and to spare in connection with the laboratory experiments. To require a written account of the lecture-table experiments, in addition to the laboratory record, is to exaggerate this phase of the work beyond all reasonable proportions and to impose an intolerable burden on the class.

The equipment of apparatus for the class room should be entirely separate from that of the laboratory, and should be stored, ready for use, in an apparatus room directly behind the demonstration table. The table itself should have drawers and closet spaces of various sizes, for the convenient storing of apparatus and supplies most frequently used, such as burners, stands and supports of various sorts, glass and rubber tubing, tools, etc.

A fairly complete equipment of apparatus for the lecture table will cost from $800 to $1,000; and $500 will be necessary for a fair beginning. It is better to start both the laboratory and the class room equipment in a modest way, and to add to each from year to year, than to expend all available funds for either alone.

Provision is rarely made as it should be for the class-room experiments in light. Direct sunlight is not at all necessary in the laboratory, but in the class room it is very important. One side of the class room should have a southerly exposure; and a window near the front of the room on this side should be equipped with a board shutter, through an opening in which a sunbeam can be directed horizontally into the room, from an adjustable porte lumiere. The proper adjustment throws the beam over and along the lecture table, at a height of ten or twelve inches, where it can be used for all experiments on reflection, refraction, dispersion, and color. Sunlight is beyond comparison the best and most convenient light for the class-room experiments on these topics. For most of the experiments in light the room should be perfectly dark. This requires an opaque shade for each window, in addition to the ordinary translucent shade. Both shades must be wide enough to project two or three inches into the deep grooves of a special box window-casing; and these grooves should be painted black.

THE PREPARATION OF QUALITATIVE "KNOWN" SOLUTIONS.

By Louis J. Curtman,
College of the City of New York.

In a recent article,[1] the advantages of the use of qualitative "unknown" solutions prepared on a quantitative basis were pointed out; a table was also supplied by means of which these solutions could be rapidly and accurately prepared. Gratifying as the results of this system have been at the college where it has been in use for two years, the full benefits of this method can only be obtained when the "unknowns" are preceded by "known" solutions made up on a similar quantitative basis.

To the conservative teacher in qualitative analysis, this departure from strictly qualitative lines may seem uncalled for; but a consideration of a few reports of qualitative analyses carried out on the old system will, it is believed, thoroughly convince him of the absolute necessity of introducing the quantitative factor in qualitative analysis. Indeed, without it a complete qualitative analysis on the old lines is almost worthless, as the following examples will make evident:

Report 1. Metals found: Fe, Al, Ca.
Acid radicals: PO_4, SO_4, SiO_2.
Report 2. Alloy contains Fe and Mn.
Report 3. Alloy consists of Fe and C.
Report 4. Metals: Mn, Fe, Ca, Mg.
Acid radicals: SiO_2.
Report 5. Metals: Ba, Sr, Ca.

The substance of Report 1 was an iron oxide ore containing as much as 60% of iron, yet the student from his analysis judged it to be a complex silicate of iron and aluminum mixed with $CaSO_4$ and $Ca_3(PO_4)_2$. The substance of Report 2 was a steel containing a little manganese. From the results of his analysis the student considered it an alloy of Fe and Mn. The material of Report 3 was a sample of cast iron, which was regarded by the student to be essentially a carbide of iron. The sample of Report 4 was a zinc ore; zinc was not reported, and the substance was considered a complex silicate of manganese, iron, calcium, and magnesium. The material of Report 5 was a solution of commercial $BaCl_2$, containing relatively small amounts of strontium and calcium. The presence of the latter elements

[1] This Journal: Vol. X, No. 6, 1910, p. 513.

was determined solely by their flame reactions. These false conclusions may seem slightly exaggerated, but the fact remains that they are daily made in qualitative work in which the quantitative feature is not emphasized. No such erroneous conclusions could have been reached concerning the nature of the substance submitted for analysis if, in the course of his work, the student gave attention to the proportions in which the components were present. These and similar cases demonstrate the necessity of a good qualitative analysis establishing not only the presence of certain ingredients, but also, though roughly, their quantitative relations; for it must be evident that without this quantitative information a correct idea of the composition of the unknown can not be formed.

It is the purpose of this article to give the method of preparing and using solutions of known strength which in our laboratories have given uniformly satisfactory results. As with the "unknowns" the exact strength will depend upon the scheme of analysis employed. In our work on the metals we prefer schemes of analyses in which precipitation reactions are almost exclusively used because of the indications they strikingly supply concerning the quantities of the metals precipitated. The figures supplied below are for stock solutions of one liter quantity. It is a good plan to prepare 5 or 10 liters of these solutions at one time and thus provide oneself with sufficient to last for several terms. In order to prevent the possible loss of such large quantities of solutions through accidental breakage of the bottle and to preclude the possible contamination of the entire stock in consequence of carelessness of students, we find it a good plan to place in the laboratory, on a shelf of convenient height, one liter of the solution contained in a bottle provided with a siphon and pinch-cock. Each bottle bears a label supplying the following data:

1. The volume of the solution to be drawn off for analysis.
2. The number of milligrams of each metal contained in this specified volume.

The advantages of the use of known solutions prepared to contain definite quantities of metals are: first, the size of the precipitates may be controlled by the instructor and those of unwieldy bulk avoided; second, and this is the chief advantage, that in addition to familiarizing himself with reactions and separations of a particular group of metals, the student also learns the *relation between the quantities of metals present and*

the size of the precipitates which they yield. The quantitative information thus acquired in the analysis of "known" solutions is subsequently applied to the analysis of "unknowns," with the inevitable result that the student is able to report not only the components present but also, though roughly, the quantitative composition of his "unknown." In consequence of this training; the student finds little difficulty in distinguishing between a trace and a significant amount, and is able, at the conclusion of his analysis, to make an intelligent statement as to the identity of the substance submitted for analysis.

In deciding on the strength of these known solutions, it is believed that the two extremes have been avoided. They are neither of such high concentration that satisfactory results can readily be obtained by the careless worker, nor are they prepared of such low strength that only the most careful and painstaking can obtain good results. Allowance has also been duly made for the inexperience of the beginner; and it has been our experience that unless the student exercises a moderate amount of care, he will find it necessary to repeat his analysis to get satisfactory results.

With solids such as salts, ores, and alloys, the same quantitative principle may be followed by requiring the student to weigh out a definite quantity for analysis. In general, 1 to 1.5 grams of an ore and from 0.5 to 1 gram of an alloy will be a convenient amount.

Preparation of "Known" Solutions.

Group 1. To prepare 1 liter of solution of strength such that 25 c.c., the volume the student takes for analysis, shall contain—

50 mg. Ag,
25 mg. Hg,
125 mg. Pb,

dissolve the following salts, in amounts given in Column 2 of the table below, in water, and then make the volume up to 1 liter:

SALT	Quantity to be dissolved in water
$AgNO_3$	3.2 g.
$HgNO_3 \cdot H_2O$	1.4
$Pb(NO_3)_2$	8
Conc. HNO_3	10 cc.

Group II. Division A. The Copper Group.

25 c.c. of solution to contain—

50 mg. Hg″,
100 mg. Pb,
50 mg. Bi,
50 mg. Cu,
100 mg. Cd.

SALT	Quantity to be dissolved in water to make up to 1 liter
$Hg(NO_3)_2 . \frac{1}{2}H_2O$	3.3
$Pb(NO_3)_2$	6.4
$Bi(NO_3)_3.5H_2O$	4.6
$Cu(NO_3)_2.6H_2O$	9.3
$Cd(NO_3)_2.4H_2O$	11.1
Conc. HNO_3	In sufficient quantity to keep the solution clear.

Group II. Division B. The Tin Group.

25 c.c. of solution to contain—

50 mg. As‴
50 mg. Sb‴
100 mg. Sn^{iv}

SALT	Quantity to be dissolved in water to make up to 1 liter
As_2O_3	2.6
$SbCl_3$	3.8
$SnCl_4$	8.7
Conc. HCl	In sufficient quantity to keep the solution clear.

Group II. Divisions A and B.

25 c.c. of solution to contain—

50 mg. Hg″,
100 mg. Cu,
100 mg. Sn,
50 mg. Sb.

SALT	Quantity to be dissolved in water to make up to 1 liter
$HgCl_2$	2.7
$Cu(NO_3)_2.6H_2O$	18.6
$SnCl_4$	8.7
$SbCl_3$	3.8

Group III.

25 c.c. of solution to contain—

100 mg. Al,
100 mg. Cr,
50 mg. Fe''',
100 mg. Ni,
50 mg. Co,
50 mg. Mn,
100 mg. Zn.

SALT	Quantity to be dissolved in water to make up to 1 liter
$AlCl_3.6H_2O$	35.9
$Cr(NO_3)_2.9H_2O$	30.8
$FeCl_3.6H_2O$	9.6
$Ni(NO_3)_2.6H_2O$	20
$Co(NO_3)_2.6H_2O$	10
$MnCl_2.4H_2O$	7.2
$Zn(NO_3)_2.6H_2O$	18.2

Group IV.

25 c.c. of solution to contain—

100 mg. Ba,
100 mg. Sr,
50 mg. Ca.

SALT	Quantity to be dissolved in water to make up to 1 liter
$BaCl_2.2H_2O$	7.2
$SrCl_2.6H_2O$	12.2
$CaCl_2$	5.5

Group V.

25 c.c. of solution to contain—

50 mg. K,
100 mg. Na,
50 mg. NH_4,
50 mg. Mg.

SALT	Quantity to be dissolved in water to make up to 1 liter
KNO_3	5.1
$NaCl$	10
NH_4Cl	5.9
$MgCl_2.6H_2O$	16.8

Known solution for all groups.

25 c.c. of solution to contain 100 mgs. of each of the following: Ag, Cu, Al, Co, Mg, K, and NH_4.

SALT	Quantity to be dissolved in water to make up to 1 liter
$AgNO_3$	6.3
$Cu(NO_3)_2.6H_2O$	18.6
$Co(NO_3)_2.6H_2O$	20
$Ca(NO_3)_2.4H_2O$	23.6
$Mg(NO_3)_2.6H_2O$	42.5
KNO_3	10.3
NH_4NO_3	17.8

PHOSPHATE MINING BREAKS RECORD.

United States Geological Survey Figures Show Production for 1910 over Two and a Half Million Tons.

The mining of phosphate rock for fertilizer showed increased activity in 1910, with the greatest production in the history of the industry. The output was 2,654,988 long tons, against 2,330,152 tons in 1909. Prices, however, were lower, the value of the 1910 output being $10,917,000, or $4.11 per ton, against $10,772,120, or $4.62 per ton, for 1909. Nearly half of the phosphate rock produced in 1910 was exported, the shipments being 1,083,037 long tons. In 1909 the exports were 1,020,556 long tons. These and other statistics of production, exports, imports, etc., are given by F. B. Van Horn, of the United States Geological Survey, in an advance chapter from "Mineral Resources" for 1910. A copy of the phosphate report may be obtained by request from the Director of the Geological Survey, Washington, D. C.

According to Mr. Van Horn, there are at present five producing phosphate fields in the United States. In the order of quantity of production they are (1) Florida, (2) Tennessee, (3) South Carolina, (4) Arkansas, (5) Idaho, Wyoming, and Utah.

By far the largest of these fields is the Idaho-Wyoming-Utah field, where enormous deposits of high-grade phosphate rock, recently discovered, are available for mining. The field next in available unmined rock is probably Tennessee, where large areas are underlain by deposits of high-grade rock. Florida has a large reserve tonnage, but at the present rapid rate of mining it will not be many years before the rock will be exhausted.

South Carolina has been mining phosphate rock since 1868, and the production has steadily declined since 1889, with the exception of two or three years, when a slight increase in production was noted.

Arkansas has never been much of a factor, and, so far as known, the deposits of this state are not of great extent.

A WORD TO ZOOLOGY TEACHERS.

By Worrallo Whitney,
Department of Zoölogy.

In comparison with other departments of science and with mathematics as well, the biological sciences, zoölogy and botany, are not well represented by papers in School Science and Mathematics. In fact, the representation is so poor that subscriptions have been cancelled by biology teachers for this reason. Why are biology teachers so reluctant to write papers? For one, I am not ready to admit that we are any less active and making any less progress in the teaching of biological subjects.

Thinking carefully over the matter, I have come to the conclusion that is due largely to the less definite character of our problems. In physics and chemistry and mathematics the problems are definite and limited; consequently there are as many points of attack as there are problems, and these are perfectly well known. But in zoölogy and in botany as well there is no well-marked procedure, neither are the problems generally agreed upon nor well defined or limited in scope. The content of the course given in zoölogy varies greatly in different schools, and so does the point of attack in these courses. It has occurred to me that this indefiniteness might be the cause of the lack of articles on zoölogical topics in zoölogy.

The Editors of School Science and Mathematics and the Editor of the Department of Zoölogy are anxious to have a better representation from zoölogy teachers. They are not so anxious for general papers on school policies or methods as for papers on definite circumscribed topics, as, for example, successful methods of keeping bees in a laboratory for observation; a simple and successful method of keeping ants; the outdoor laboratory, etc. I append below a tabulated statement of some topics which are uppermost now in the minds of teachers of zoölogy. If you have had some experience or have been experimenting on any of them write us a short paper. It need not be long; in fact, short papers are much preferred.

1. The problem or topic method of studying zoölogy as opposed to the evolutionary method.

2. Can zoölogy be taught as a series of problems?

3. The outdoor laboratory as an auxiliary of the laboratory indoors.

4. How to bring zoölogy into closer touch with everyday experience.

5. How can the subjects of mammals and domesticated animals be taught to high school classes in zoölogy?

6. How are the insects best taught?

7. How should classes be introduced to zoölogy?

8. Practical devices.

Many more topics could be mentioned. If you have something to write or know of somebody who has, let us know.

AN OPEN BOOK TEST.

BY A. P. ANDREWS,
Department of Physics, Central High School, Minneapolis.

During the semester which closed last June, a departure from the usual method of conducting tests was tried with three classes in second term physics at the Central High School, Minneapolis. The writer has no information that the method has been tried anywhere except in connection with correspondence schools, but even if it has, the same experiment by another person often brings out something new, and this fact forms the only excuse for setting forth the results in this particular case. To state the point at once, the students were given their monthly tests with permission to use their text-books for reference as much as they pleased. The outcome has been so encouraging that it is probable the old way will never again be revived. At any rate it is planned to continue the method during the whole of the present year and it is confidently expected to fix the conviction that a means has been hit upon for doing away with two of the greatest evils that accompany the usual method of giving tests, namely, cramming and cheating, and not only that, but there is good reason to believe that the new plan will have a definite effect in making students think, where under the old order mere memorizing so often served the purpose.

The experiment grew out of a desire to eliminate as far as possible the two evils that have just been mentioned. This desire in turn sprang from a fuller realization of the far-reaching and demoralizing effects of these practices. The habitual indulgence in cramming or cheating or both is in itself very deplorable. That this should occur during the most impressionable years of a student's life is far worse. But the trouble does not

end even there; this is but the beginning, the end of which is wrong notions of study and work, the forming of pernicious mental and moral habits, all with resulting general inefficiency. Such conditions are not improved materially by moral dissertations upon them nor by policing the subjects to whom these discourses are directed. Some more effective measure must be sought, something that will as inevitably drive the student to a beneficial method of preparing for a test as the present system drives him to cram; that will as far as possible reduce the temptation to cheat, and will take away all justification for dishonesty. The consideration that had most to do with suggesting the open book plan was the fact that examinations as ordinarily conducted do not test a student in a way that corresponds to the trials he will meet in real life. I think this idea, although very likely not at all clear to the student, is the justification that underlies the prevailing idea that there is no great wrong in soliciting or giving aid in a test. I believe the student realizes in a vague sort of a way the impracticableness of the ordinary test and feels that when once out of school he will probably never again meet with anything even remotely similar. In real life he will not want to cheat if he is looking for true success. Neither can he on previous notice "cram up" with knowledge as to how this or that matter of business is to be adjusted. He must be prepared it is true, but it is not the preparation that is made by cramming that will help him out. Furthermore, in a test we label as dishonest a thing which in real life is perfectly right and honorable, in fact, we prohibit our students from doing a thing which in real matter of fact experience becomes absolutely indispensable. I refer to the use of books as reference. In no profession can all of the vast amount of knowledge bearing upon it be carried in the memory of any one person. It is the exceptional man in any calling who does not need assistance of this nature *and need it when he is right at work on his problem.*

Why not then place the student in circumstances as nearly as possible like those in which he may some day actually find himself? The open book test seemed to supply these conditions better than anything else that would suggest itself and a trial was decided upon. This decision was reached toward the end of the first semester of last year and only a few days before the final test which was to cover the subject of electricity. In announcing the time for this test and in explaining the nature of it, the only warning given the students was that the questions would be

of such a character that the answers could not be copied from the books, that there was to be a test as to their understanding of the subject-matter covered and not merely of their ability to restate facts and principles. In each of the three classes concerned the average mark was much below any of their previous averages. This was caused more by a greater number of pupils receiving low marks than by a general lowering of all marks. A few who had always had good standings failed almost completely. There were also some that did as well or better than in the closed book test. The experiment as judged from these facts would seem to expose the weakness of the old style of test. It would seem to indicate that many students in their daily work had obtained only a superficial understanding of the principles gone over, relying on the usual cramming process to carry them through. When, however, they were subjected to a test which depended almost entirely on the understanding, they were unable to make their usual showing.

The next semester, the one ending last June, the open book test was used exclusively. At the very beginning of the first month the system with its purposes was fully explained to each class. The object was to emphasize the importance of obtaining from day to day a complete understanding of every point to be studied. The nature of the test looming up ahead was to serve as a constant reminder that nothing short of thorough comprehension would suffice. In the daily work too the same idea of openness was carried out. For example, most students have the notion that if they employ outside help they are doing something that will meet the disapproval of the teacher. In contrast to this the students were made to feel that it was perfectly legitimate to obtain outside aid from any source, insisting rigidly, however, that whatever information was obtained in this way must be comprehended, and that a perfectly clear and understandable explanation would be expected whenever called for. This policy has served to establish a more free and open relation between teacher and pupils than has been before experienced. Students seem to regard their instructor more as a fellow with whom they may freely discuss their lessons and difficulties than as a policeman on the alert to spot them in some transgression.

In the open book style of test no options on questions are allowed. With the increased facilities at hand for doing work afforded by the open book it seemed no more than fair that all questions should be answered. Also, it is required that more

ground be covered in the same time. The reason for these requirements is to ensure preparatory work on the part of the pupil. The test must not be of such a nature that the student can risk coming to it unprepared. What he does not know offhand he must know where to find. The test must be stiff enough so that the average boy or girl will be made to put forth his best efforts during the entire time devoted to the test.

At the close of the term each student was asked which kind of test he preferred and why. Out of seventy-two sixty-four preferred the open book method, six the closed, while two had no preference. The predominating reason given for the choice of the open book method was that suggestions could be obtained. A large per cent said they had more confidence in themselves, and a number declared that they were relieved of the dread and nervous strain with which they had previously faced a test. The choice on the part of a few was based on the statement that it was easier, but the large majority found it necessary to spend as much time in preparation as before.

One answer closed with the following rather philosophical sentence which states correctly what should be the purpose of every test: "An examination should test the logical working of the mind rather than exhibit the result of temporary memorizing."

In thus briefly describing this method of testing students I have dwelt only on its advantages. So far in my experience no serious defects have been noticed. In this style of test as in every other much depends on the character of the questions. The possibilities in questioning were discussed in a very valuable paper by Professor E. L. Thorndike read at the meeting of the American Association for the Advancement of Science in Minneapolis in December, 1910, and printed in the April number of SCHOOL SCIENCE AND MATHEMATICS. Suggestions of great value that are applicable to both open and closed book tests are contained in this paper, which is worth a careful study by every teacher interested in raising the standard of student testing. However, as I have tried to set forth, the open test seems to me to possess some advantages over the closed. Limited to subjects in which the predominating purpose is the development of reason, the "open test" ought to be found as practicable as the "open door" and the "open shop."

PHYSICAL GEOGRAPHY IN THE HIGH SCHOOL.

By E. E. Ramsey,
Bloomington, Ind.

INTRODUCTION.

Origin and purpose of the report. This report embodies the results obtained from two questionnaires, one of which was sent out by the teacher of physical geography in the Critic School of Indiana University and the other by Dr. J. W. Beede of the Department of Geology in the same institution. The first list was sent to teachers of Physical Geography in High Schools of the Middle West and the second to professors of geography and geology in the various normal schools, colleges, and universities of the United States, known to have courses in these subjects.

About 125 lists of questions of the first class and 26 lists of the second class were sent out. The total number of positive reports received from the high school questionnaire was 63; the total number of schools replying that they had no geography in their courses was 23, making a total of 86 schools reporting. Of the 23 schools having no geography, 18 were in Indiana. The number of schools reporting from Indiana was 52; this makes approximately 33⅓% of the schools of this state not offering the subject. The list of schools addressed embraces schools of practically every type and size, so that it is fair to assume that the results obtained are representative of average conditions in the Middle West.

From the schools to which lists of the second class were sent, 21 answers were received. Three lists were returned from normal schools, one list from colleges, and 17 lists from universities.

The answers indicate that much careful thought has been given in their preparation. They develop many points which are fundamental in the pedagogy of the subject. Although the answers are from widely different sources, there is a remarkable consensus of opinion upon many of them. The two questionnaires cover practically the same ground. The plan thus gives the secondary view and the university view of the subject. The writer believes that the questions sent out are questions that are fundamental in the teaching of geography, and hopes that the results obtained will unify, in some measure, the teaching of the subject. In the past, physical geography has been one of the "scrap heap" subjects—one to be taught by whatsoever teacher needed "one more subject" to complete his schedule. This condition has led

to bad teaching, and geography is yet—largely because of this condition of schedules—the least developed of the sciences of the high school.

High School List.

The following is a list of the questions sent to high schools:

1. School in which you are now teaching.
2. What subjects are you now teaching?
3. In what school did you receive your training?
4. What amount of time did you devote to physical geography and geology during your college course?
5. How long do you devote to physical geography in the high school?
6. In what year's work is physical geography taught?
7. What science or sciences follow it?
8. What science or sciences precede it?
9. Give your reasons for or against placing the subject in the year given.
10. What amount of time do you devote to recitation work?
11. Do you have laboratory work?
12. What amount of time is given to it?
13. State rather fully the nature of your laboratory work.
14. How much field work do you do?
15. State the plan of your field work.
16. What idea do you have in mind in doing field work?
17. Is your time for field work limited?
18. If so, how do you overcome this difficulty?
19. State the changes, if any, that you would recommend in recitation work, field work, and laboratory work in order to bring about better results in physical geography?
20. Do you teach the subject from the geocentric or from the anthropocentric viewpoint?
21. What amount of time in a nine months' term should be allotted to the following topics?

Mathematical Geography ....
Weathering ....
Rivers and river action ....
Glaciers and glaciology ....
Mountains ....
Vulcanism ....
Meteorology ....
Plant Geography ....

Animal Geography ....

Geography of man ....

NOTE. Answer the above question with the understanding that this distribution may be modified, if many peculiarly adaptable local forms are present.

22. State what you think the values of physical geography as a high school subject are.

23. Is physical geography as well adapted as a high school subject from the standpoint of subject-matter as the biological sciences, or as physics, or as chemistry?

24. To what extent do you use models, contour maps, and intricate apparatus in laboratory work and in demonstration work?

25. Do you use any elementary chemical and physical experiments for their bearing on physical geography?

26. Give a list of them.

27. How much work on meteorology do you do?

28. Does meteorology possess any advantages over other phases of physical geography as a high school subject? If so, what?

The following pages are devoted to the results obtained, together with discussion of these results.

Question 2. What subjects are you now teaching?

The purpose of this question was to determine in how far special teachers are employed in physical geography. As compared with conditions which obtained some years ago, the situation is much improved. In the 62 schools reporting on this question, 3 teachers had physical geography only; 40 had only science subjects (physical geography, zoölogy, botany, biology, physiology, commercial geography, geology, physics, chemistry), while 4 had in addition to geography taught one subject outside the science departments, 15 had combinations of geography, other sciences, and subjects outside of the science departments. This makes 43 schools—60% of the total—which have their teacher of physical geography employed in such lines of work that they tend to strengthen the teaching of the former subject.

The total number of subjects taught by the 62 teachers is 167. Of these 137 are science subjects.

Question 3. In what school did you receive your training?

Names of schools given in the various reports are purposely omitted. It is sufficient to say that the four schools the names of which appear oftenest in the lists of answers are schools whose courses in geology and physiography are recognized as

being of a *high standard*. Forty-two normals, colleges, and universities are named.

Question 4. What amount of time did you devote to physical geography and geology in colleges?

In reporting the results of this question, the system under which high schools are at present conducted rather than the teacher is believed to be at fault. It is certainly not expecting too much of school authorities to furnish a teaching force which is sufficient to care for the work without requiring a teacher to care for two, three or four unrelated subjects, or to assume responsibility of a subject in which they have had no training. The following table shows the amount of training:

4 years' work or more	3
3 years' work	2
2½ years' work	3
2 years' work	8
1½ years' work	4
1 year's work	22
1 semester's work	7
No work	12
No answer	3

There is no science, however, in which specific training may be dropped with less loss to the subject involved than in physiography, provided the teacher possess a broad knowledge of other sciences. But this should not be urged as an argument against better training of teachers in the field of geography.

Question 5. How long do you devote to geography in the high school?

Sixty-one schools reported on this question. Of this number 34 have a full year's course in the work and twenty-seven do the work in one semester. Quite a number of schools completing the physiography in one term take up commercial geography for the remainder of the year. By this means quite a few of the physiographic phases of the geography of plants, of animals and of man can be dwelt upon with sufficient length to partially compensate for the one semester's work in physiography. In the answers to a succeeding question, the question as to the position of the subject in the course, when one semester is given to it, is given. Thirteen of the 27 schools have the one-semester course in the freshman year. In the senior group, the work is evidently taken up from the synthetic standpoint, since but one of these schools has any science work following it. It is notice-

able that there is no school having a year's work in the senior year.

Question 6. In what year's work is physical geography placed?

The subject has a lead as a freshman subject. A significant contrast exists in the data for Indiana high schools and that for all other high schools from which answers were received. The following is a summary of the answers:

YEAR	Indiana H. S.	All Other H. S.	% for Indiana	% for Others	Total %
Freshman	15	21	23.8	33.4	57.2
Sophomore	7	6	11.1	9.5	20.6
Junior	4	1	6.3	1.6	7.9
Senior	6		9.5		9.5
Elective above Freshman	1	1	1.6	1.6	3.2
No answer	1	1	1.6		1.6
Total schools	34	29			

The Indiana high schools have the subject scattered through all the years of the course, although the number presenting the subject in the freshman year is greatest. Schools outside the state have the subject either in the freshman or sophomore years. The uniformity of position of the geography in the latter group of schools can only tend to give the subject more fixed and rational methods of treatment than is possible under the conditions found in Indiana high schools.

Question 7. What science or sciences precede it?

Ascertaining what science or sciences precede physical geography in the course is fundamental in selecting a method of teaching the subject. Physiography is not a fundamental science. The study of meteorology is largely a study of the chemistry and of the physics (particularly the latter) of the atmosphere. The study of zoögeography and of plant geography involves some general conceptions drawn from zoölogy and botany. The geography of man draws upon anthropology and ethnology, touches upon the history of the development of the various arts and crafts, traces the history of the material progress of the race, with its mental and institutional growth. Here alone is a contact with many lines of thought. It is practically impos-

sible to give a definite line of demarcation between geology and physiography. Theoretically, the definitions are sufficiently distinct that it would seem that no question of interpenetration of these two subjects could arise. But the practical condition of the subjects may be found by examining texts on physiography and geology written by the same author and noting the great amount of duplication, especially in the dynamic phases. The study of such topics as rocks and soils, weathering, rivers and river action are all quite largely physical and geological and chemical in character. It is essential either that the student have the various sciences in which the geography has its footing and thus approach the subject from the synthetic viewpoint or that he approach it from the analytic viewpoint, and in so doing be given the elements of the foundation sciences underlying geography. These two methods of treatment are so radically different that it seems to be vital to settle where in the course in geography each should come and then have the methodology of the subject conform to the accepted position. Of 61 schools reporting on this question 33 report physical geography as the first science offered in the course; of these 30 place it in freshman, 2 in sophomore, and 1 in junior work. Six other schools teaching it in the first half of the freshman year, thus making a total of 36 schools teaching it in the freshman year. Twenty-four of the 36 schools have a full year's course.

Six schools report full year courses in the sophomore year and seven have semester courses. Botany is the freshman science in eleven of these schools, physiology and zoölogy in the other two.

Three schools have full courses in the junior year, and two have semester courses. Six schools have semester courses in the senior year. Two schools report courses elective in any year above the freshman.

Question 8. What science or sciences follow physical geography?

The answers to this question furnish definite evidence of the trend of science work. It has been pointed out that 59% of the schools reporting place physical geography as the first science; further, that approximately 50% of them place it as the freshman science; the other 50% is divided among botany, zoology and physiology. The data secured shows that, from the 61 schools answering the question 17 of them placed zoölogy after geography, 27 placed botany after, 42 had chemistry fol-

lowing it and 52 had physics following it. Zoölogy and geography, 6 times; botany, 22 times; chemistry, 2 times; physics, 4 times.

GEOG.	Given Precedence Over	Geog. Not Given Precedence Over
Zool.	In 17 cases	In 6 cases
Bot.	In 27 cases	In 22 cases
Chem.	In 42 cases	In 2 cases
Phys.	In 52 cases	In 4 cases

Question 9. Give your reasons for or against placing the subject in the year given.

In answer to this question the arguments are brought out for the position which geography has in each school, but there is incidentally embodied a large amount of material which bears on the value of the science as a high school subject. What is given under this heading will therefore be partially repeated in the digest of the answers to question 22. The data and discussion are given by years. *Freshman year.* The first argument against its position as a freshman subject is, "It treats of applications of laws of physics, chemistry and biology and should therefore follow them." Admitting that the first part of the criticism is true, the last part does not necessarily follow. The points of contact between physiography and the sciences above mentioned can probably be given much more simply and just as interestingly earlier in the course. There are no fundamental laws of these sciences needed in physiography that a student cannot get and indeed *should not have* at a very much earlier period than they can be secured by waiting until the embodying sciences can be given. Moreover any one of these sciences is subject to the same fallacious argument. So many specialists argue that *their* subject should come last. If the geography be placed as a senior science another science more specialized in character must be substituted in the freshman year and the lack of scientific training and knowledge is again bemoaned. The second says, "It is difficult because it is so new; the students are unprepared for scientific methods." Of the five or six sciences offered in high school, which one will be any less new to the average class? Further, the question is not as to whether the child coming to high school is unprepared for scientific meth-

ods—he commonly is and undoubtedly normally so—but rather in what subject he can find this training best. "Pupils do not see the value of geography." At the time at which this questionnaire was sent out, lists of questions were sent out to high school students. About 150 replies were received from them. The answers show that students of physical geography can and do see the value of the subject. "The freshman is not a close observer." It takes a year of some science to make him a close observer. The character of observation in physiography is grosser is upon larger masses and quantities and is therefore better suited to the inception of methods of observation than other sciences. The question of weather observation, of stream action, does not involve such close scrutiny as does the sectioning of a leaf or the successful manipulation of a microscope. "The subject should be placed in the sophomore year, because the lack of concrete material necessitates a mature mind." The sky and the clouds, the air and its moisture, the land and the sea, the mountains and the lakes, the plateaus and the rivers, the plants and the animals, and man himself are its concrete materials. "Should be in the junior year because it is not basal for the sciences." There is probably no science so *nearly basal* for all the high school sciences as is geography. In the arguments for placing the subject in the freshman year, the belief that physiography is a foundation science predominates. Of 29 teachers who argue for this position of geography in the course, 14 mention its value as an introductory or as a foundation science. This combination of geography and introductory science can be made satisfactorily if the geographic elements are given the right of way and the elementary science, as such, left in the background. Much elementary science can be given in this way—quite as much as is usually given in courses purporting to be such. The elementary science will then have a skeleton upon which to support a body. If some of the works on elementary science *are* elementary science, then may we be delivered from the bondage of such work, and substitute something, anything, that has *continuity*. Five reports speak of the fact that physical geography normally belongs in the first year, because of its connection with grade geography. This seems to be proceeding from the known to the unknown in a perfectly logical way. Twelve speak of the fact that no science is so well suited to this stage of development of the student as is geography. This question of its adaptability is of course one of the

most fundamental of all questions with regard to its position. The fact that the subject is broad makes it especially adaptable to the young mind. Its subject matter is very concrete, although this argument may with validity be used with reference to the other sciences. The fact that there is an opportunity to observe the phenomena under more natural conditions than in other sciences contributes to the value of this science. This presupposes that some kind of field work—either class work in the field, the work of individual students in the field, or the observations of students previous to their study—is possible. Some one of these lines of observation work is undoubtedly feasible.

The subject creates an early interest in science and gives in general form the method of science study. The latter is true only when intelligent laboratory and field work are followed. It is also pointed out that the subject matter is common and that the nomenclature is neither difficult nor extensive. These two points when taken together are worth careful consideration. Certainly no phenomena are more common and there are comparatively few terms that are outside the average student's vocabulary. This minimizes the amount of definition work necessary. Many students quit the high school with the freshman year. Two answers say that because of this fact, the student taking physical geography during this year will quit school with a better knowledge of his larger environment than could have been obtained through the study of any other science.

Three other answers state that geography is basal for biology, commercial geography and history. Considerable emphasis is now placed upon ecology in the study of the biological sciences. The ecological contact is simply the contact with environment, of which the physical environment constitutes a larger part than the biological; consequently the value of the subject in the interpretation of botany and zoölogy, manufacturing, commerce and production are always conditioned by the same physical environment as life; to which may be added of course the contribution of natural resources. The study of geographic influences in history has recently had considerable attention paid it; enough to clearly warrant the above statement. Finally, the fact that easy laboratory and field work can be arranged is argument for placing the work in a position early in the course. Later on in this report the difficulty of field work is pointed out. This is an universal complaint in the sciences and is not peculiar to geography. The difficulties of field work in this subject are but

little, if any, more involved than are those relating to the same question in zoölogy and botany.

Sophomore year. In some schools geography is the first science offered, and is in the sophomore year. Quite a little of the argument therefore for placing geography in the freshman year is also given here. That it is a foundation science and that it connects with grade work are both given. Its contact with more students if given earlier in the course is mentioned. Lastly, the argument that the students are more mature is used. It seems that all such argument as this should be eliminated, because its logical and extended use would eliminate the subject from the high school course.

Junior year. One answer states that it can be made more scientific than in earlier years. Another school that has had geography in the junior year is now trying the subject in the freshman year with a view to placing it there permanently.

Senior year. One school having geography as a senior science argues against its position there by saying that it is less difficult than physics and that a student should receive some scientific training early in the course. Four schools argue for the work in this year by saying that the study of physics (3) and other sciences (1) render physical geography more intelligible.

Four schools do not attempt an answer, a few facetious answers are included, and a few are irrelevant.

Question 10. What amount of time do you devote to recitation?

Sixty-one lists answer the question, ten in terms of hours per week.[1] The other answers have been reduced to this basis as nearly as possible.

(1) Five hours per week. 26.
(2) Four hours per week. 8.
(3) Three hours per week. 13.
(4) Two and one half hours per week. 6.
(5) Two hours per week 3.
(6) Two thirds of time. 2.
(7) Nine tenths of time. 1.
(8) Three fourths of time. 1.
(9) No answer. 3.

Question 11. Do you have laboratory work? Question 12. What amount of time is given to laboratory work?

[1] Hereafter, when numbers in parenthesis appear in the body of a sentence or at the end, they indicate the number of answers credited to the particular point in which the number is found.

Forty-three schools report laboratory work in varying amounts; 16 report no laboratory work, and 4 do not answer. It is fair to assume that these four do not have laboratory work, thus making a total of 20. Every school that has fewer than five recitations per week has laboratory work. From the 26 schools having 5 periods of recitation per week, 16 have no laboratory work, one does not answer, and 9 have some laboratory. Two of these spend one-half period per week; two one period per week; three two periods per week; and one four periods per week.

The average time spent by all schools in laboratory work is somewhat less than 2 periods per week.

No school states that double period time is allowed them for physical geography work. The interpretation of this fact is that this science is not placed on an equal footing with other sciences.

Question 13. State rather fully the nature of your laboratory work.

Because of the fact that not all schools have laboratory work there were but 46 schools reporting. The suggestions as to the nature of the laboratory show considerable uniformity in the selection of material. Twenty-two schools base some of their laboratory work upon contour maps. Seven others mention a rather widely used manual of geography, which contains much work in contour maps. This makes a total of 29 schools using such materials. Twenty-two use "rocks, minerals and soils" as a basis for laboratory work. Twelve of these schools mention the study of rocks and minerals. It is highly probable that this line of work can easily be overdone without securing results which will be of vital importance to physiography. Too much energy and time will be given to them for their own sake. The making of weather maps and the keeping of weather records is mentioned by 25 schools. Under the same general heading of meteorology, three mention studies of the atmosphere. Rainfall charts and maps, winds, forecasts, isothermal maps, graphs of thermometric, barometric and rainfall conditions are suggested.

(To be Continued.)

TESTING RESULTS IN SCIENCE TEACHING.

By Fredus N. Peters,
Central High School, Kansas City, Mo.

Considerable has been said and written the past year regarding methods of testing results obtained in science teaching. It is possible that we all feel, taking into consideration all the circumstances, that we are doing fairly well; but the question is, are the results what they should be or even what we think they are?

As to how results in science teaching may be tested, there does not seem to be any well-defined idea. In geometry it has been the custom for years to give the student a greater or less number of "originals" throughout the course. Undoubtedly these test the ability of the student to apply what he has learned and show fairly well what results have really been obtained.

With this in mind, in our laboratory last winter we attempted what we called "originals in chemistry." They were all related in some way to work which had been done, just as would be the case in geometry. A few of these experiments are outlined below almost exactly as they were given to the students.

I. This problem was given December 10:

"1. Weigh out accurately one gram of bright blue copper sulphate crystals; dissolve in 25 c.c. of distilled water.

"2. While above is dissolving, weigh a strip of zinc, about one half inch by two inches. Bend into a coil and put into the solution of copper sulphate. Remove as soon as the color of the solution is completely gone. *This is important.*

"3. Observations. (a) Dark deposit on the zinc. (b) Disappearance of blue color. (c) Corrosion of zinc strip.

"4. Questions to be determined. (a) What is the dark deposit? Any theory you may have must be proved by chemical test and approved by instructor. (b) Why does the blue color disappear? (c) Cause of zinc corrosion. Proof must be made for any theory advanced.

"5. References. Modern Chemistry, pp. 252, 7; 234, 7; 238, at top of page 70; Laboratory Experiments, pp. 78, 7; 26, 17, 18; 81, 1.

"6. Chemical equation. When you have proved your theory both qualitatively and quantitatively, write the equation. Suggestion: Carefully dry strip of zinc and weigh accurately. Results?

"7. Calculate from your equation what the zinc should lose, if at all. Compare with your results by weighing.

"8. Submit to instructor some plan you may devise for recovering accurately the compound containing the zinc. While this work is progressing, calculate theoretical amount so as to compare with amount obtained by experiment. Look up exact formula for this compound before making calculation."

Before the work had proceeded very far it became apparent to the instructor that a good many thought the dark deposit was cupric oxide, so some further notes became necessary, and the following suggestions were added to what had previously been given:

"9. Dissolve a very small amount of copper oxide in a few drops of strong nitric acid. Note character of gas obtained. Do the same with a bit of copper. Apply the same tests to the dark deposit obtained upon the zinc. Conclusions?

"Problem II. Can you prepare ferrous chloride from ferrous sulphate by treating it with hydrochloric acid? Suggestions: Do what the question

suggests; boil nearly dry with free flame; complete upon the water bath; when perfectly dry dissolve in distilled water and determine whether you have a chloride of iron."

This problem was given in the latter part of the year after some discussion of reversible equations had been had. At the same time another class was given the following:

"Problem.—If copper nitrate solution is treated with strong hydrochloric acid, is the reaction reversible or does it go to completion?"

To another class about the same time was given the following modified form of the preceding:

"Problem.—Which of the equations given below expresses the truth? Or does either one express the truth?

"a. $Cu(NO_3)_2+2HCl \rightarrow CuCl_2+2HNO_3$.

"b. $Cu(NO_3)_2+2HCl \rightleftarrows CuCl_2+2HNO_3$.

"Suggestions. Use not over one gram of cupric nitrate, dissolve in about 10 c.c. of water, add strong hydrochloric acid, about 1 c.c. Boil nearly dry over free flame, finish on water bath, heating till acid fumes no longer come off. (How can you know?) Dissolve in water and make necessary tests to answer above questions."

At another time the following was given:

"Problem.—To determine the effect of nascent hydrogen on potassium chlorate.

"Suggestions. Dissolve 0.5 g. of potassium chlorate in 20 c.c. warm water, add a few granules of zinc or a short strip of the metal, and then about 1 c.c. of sulphuric acid or enough to give a brisk evolution of gas. Allow the action to continue from 7 to 10 minutes.

"Filter, if necessary, and determine whether you still have a chlorate in solution. If not, what is there?

"Write all equations and submit report to instructor."

This problem was given after the students had had several cases of the reducing action of nascent hydrogen, for example, upon copper oxide, ferric chloride, and perhaps some others.

These are fair samples of the problems given to the classes and almost word for word as they were offered. In each case ample opportunity had been given the students to know all that was needed to carry out the work successfully. Sometimes the work bearing upon the problem had been done some time previously, but if so references were given either to the text in use or to other books.

The problems are given, not for the purpose of suggestion, but rather to invite criticism from others who may have tried similar or other plans. It is earnestly desired by the writer that other teachers of chemistry will use SCHOOL SCIENCE to state what they have been doing in the way of testing their own results in a practical way. Let us have them in a concrete form so that others of us may make a trial of the same. We may thus all profit by the interchange.

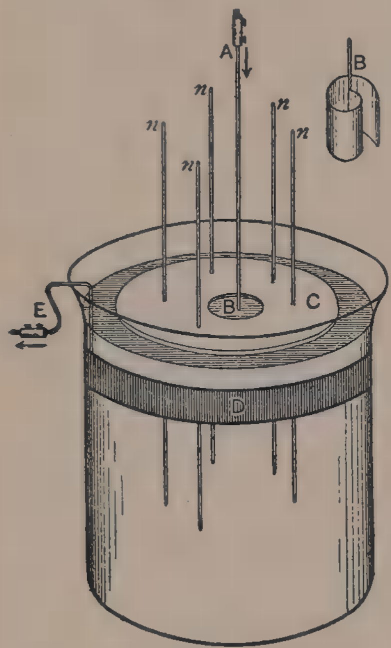
A SUBSTITUTE FOR CELLULOID.

The combustible or even explosive character of celluloid has long stimulated investigators to discover a substitute. Such a substitute, known as cellon, and manufactured in Germany, is attracting attention in this country. It may be made into a wide variety of articles. The inventor of cellon states that it is now being manufactured at Cologne and Paris, a manufacturing company is organizing in England, and an option for its manufacture has been granted to a firm in the United States.

ROTATION OF A MAGNET POLE.

BY H. E. HADLEY,
Kidderminster.

The following experiment, to demonstrate the rotation of a magnet pole around a wire conveying a current, may be new to some readers of SCHOOL SCIENCE AND MATHEMATICS. An oak disc C, about 10 cm. diameter, with a central hole 1 cm. diameter, carries five strongly magnetized knitting needles with similar poles uppermost. The needles are about 15 cm. long, and at least one half of each needle is below the surface of the disk. D is a band of thick sheet copper fitting inside a wide beaker and with a terminal wire E of thick copper soldered to it. The beaker is filled to a level above D with a strong solution of copper sulphate to which 5 per cent sulphuric acid has been added. AB is a thick copper wire terminating just below the liquid in a spirally bent piece of thick sheet copper, as shown in the inset.



When the apparatus is arranged as shown in the diagram, and a current of 4 to 5 amperes sent down AB, through the liquid, and out at E, the disc rotates in a clockwise direction if the north-seeking poles of the magnets are uppermost. The speed of rotation can be varied by varying the current strength, and the rotation of a south-seeking pole can be observed by reversing the disc. It is advisable to varnish the disc and needles.—*School World.*

LAVA FROM VESUVIUS.

BY NICHOLAS KNIGHT,
Cornell College.

During the eruption of Vesuvius in the spring of 1906, some fine, light colored, dust-like material was borne by the winds to Pompeii, and in places formed a layer two or three inches thick in the streets of the ancient city. On a visit to Pompeii the following year we secured about fifteen or twenty grams of the fine dust, an analysis of which resulted as follows:

SiO_2	47.45	%
Al_2O_3	40.86	"
CaO	3.63	"
MgO	0.80	"
TiO_2	0.16	"
CO_2	1.41	"
K_2O	2.32	"
Na_2O	1.24	"
P_2O_5	1.71	"
Fe_2O_2	0.30	"
	99.88	%

The material is therefore largely aluminum silicate.

In the great eruption of 79 A. D. which engulfed the entire city and buried it completely, several kinds of rock material were ejected. One of the interesting varieties was pumice stone. An analysis of a light gray specimen obtained there in 1908 resulted as follows:

SiO_2	52.85 %
Al_2O_3	21.79 "
CaO	7.07 "
MgO	1.60 "
TiO_2	0.91 "
CO_2	0.00 "
K_2O	6.20 "
Na_2O	6.64 "
P_2O_5	0.78 "
Fe_2O_3	2.65 "
	100.49 %

This rock is also a silicate.

Another variety of rock which contributed to the overthrow of the ancient city is what is known as lava. The specimen obtained for analysis was slightly green in color, hard, compact, and fine grained. It analyzed as follows:

SiO_2	43.21 %
Al_2O_3	31.28 "
CaO	4.85 "
MgO	2.21 "
TiO_2	0.47 "
CO_2	0.00 "
K_2O	2.54 "
Na_2O	4.57 "
P_2O_5	1.14 "
Fe_2O_2	10.26 "
	100.53 %

This is also a silicate in which aluminum predominates.

We desire to express our thanks to Miss Guinnevere Sheets, Neil T. Lutes, and Rubee J. Pearse for carrying out the foregoing analyses.

TUNGSTEN FILAMENTS.

One of the recent methods of producing tungsten filaments for lamps consists, first, of a process of converting the metal into tungsten phosphide, the phosphorus being introduced into a practically closed crucible containing tungsten particles. A phosphide ingot is secured and this is used as the cathode in an electrolytic bath, which reconverts the material into metallic tungsten in a more or less porous condition. The metal is subjected to white heat and worked by hammering and rolling. The process is repeated to render the metal more homogeneous and ductile, and the ingot is then hammered and compressed into a long drawn out rod, which is cooled and then heated and drawn out into wire by passing it through suitable dies. It is claimed that this wire is so ductile and flexible that it can be formed into any shape of filament.

ARTICLES IN CURRENT MAGAZINES.

American Forestry for October: "Fire Protection in the National Forests," Earle H. Clapp (six illustrations from U. S. Forest Service photographs); "What Oregon Is Doing to Prevent Forest Fires," C. S. Chapman; "Utilizing Troops in the National Forests," George M. Cornwall; "Basket Willow Culture in Maryland," C. D. Mell (three illustrations); "Under Minnesota's New Forest Law," W. T. Cox; "Progress of Forestry in Wisconsin," Frank B. Moody; "How One National Forest Is Protected," D. N. Rogers.

American Naturalist for September: "Inheritance of the 'Eye' in Vigna," Dr. W. J. Spillman; "Heredity of Hair Form among the Filipinos," Dr. Robert Bennett Bean; "The Zoögeography of the East Indian Archipelago," Dr. P. N. Van Kampen; Shorter Articles and Discussion; Biometric Arguments Regarding the Genotype Concept.

Education for October: "Constants and Variables in the High School Program of Studies," H. A. Hollister; "A Suggestive Outline for a One Year Course in Secondary Agriculture for Rural and Village High Schools," G. A. Bricker; "An Experiment in Free Tuition," R. T. House; "Accuracy in Arithmetic," Joseph V. Collins; "Education in England and America," C. H. Moore; "The High School Course in American Government," Louis I. Bredvold.

Educational Psychology for October: "Oxygen Supply as a Condition of Efficient Brain Activity," William H. Burnham; "A Report on the Teaching and Practice of Hygiene in the Public Normal Schools of the United States," Arthur Heche; "School Instruction in Matters of Sex," W. S. Foster; "An Experiment in Teaching Sex Hygiene," Walter Hollis Eddy.

Journal of Geography for October: "The Railroads, Industries. and Distribution of Population in Michigan," A. E. Parkins; "A New Zealand Examination in Physiography;" "Man and His Environment in Norway," Bertha Henderson; "Laying the Emphasis in Teaching the Geography of Asia," R. H. Whitbeck; "Current Events and Geography," Mary E. Kelton; "Notes on Economic Geography," Albert Perry Brigham; "General Science in Relation to Physical Geography," Everett P. Carey; "A Study of the Great Industries of the United States" (Questions); "To Set Your Watch by the Sun," Willis E. Johnson.

L'Enseignement Mathématique for September: "Un appareil démontrant la transformation de l'énergie potentielle én energie cinétique," A. Emch; "Sur la représentation des déterminants par des systèmes articulés," F. Butavand; "Sur certaines transformations de droites," E. Turrière; "Sur la théorie des coniques," G. Valiron; "Sur une théorie de la mesure," L.-E.-J. Brouwer; "Note complémentaire sur les fonctions de mesure," G. Combebiac.

Nature-Study Review for September: "Place of Forestry in General Education," Herbert A. Smith; "Forestry from Two Viewpoints," J. J. Crumley; "Forestry in Nature-Study," Edwin R. Jackson.

Physical Review for September: "The Terminal Velocity of Fall of Small Spheres in Air at Reduced Pressures," L. W. McKeehan; "Heat of Evaporation of Water," Arthur Whitmore Smith; "The Distribution of Current and the Variation of Resistence in Linear Conductors of Square and Rectangular Cross-section when Carrying Alternating Currents of High Frequency," Hiram Wheeler Edwards; "On the Nomenclature of Crystallography," Paul Saurel; "On the Positive Potential of Metals in the Photoelectric Effect and the Determination of the Wave-Length Equivalent of Roentgen Rays," Jakob Kunz.

Photo-Era for October: "The Experiences of a City Amateur," Dr. D. J. Ruzicka; "The Use of Single-Speed Shutters," Arthur Pender; "Picturing the Seasons," C. H. Claudy; "Panchromatic Plates for Landscape Work," Malcolm Dean Miller; "The Organization and Management of a Camera Club," H. Ladd Walford.

Popular Astronomy for November: "The Evolution of the Starry Heavens," T. J. J. See (Plates XVII and XVIII); "Gravity and the Earth's Motions," Hyland C. Kirk; "Radial Velocity of Halley's Comet as Derived from a Spectrogram," Edwin B. Frost; "A Simple Method for Adjusting the Polar Axis of an Equatorial Telescope," Frank Schlesinger; "A Strange Transit," William F. Rigge, S. J.; "Celestial Photography with Ordinary Portrait Lenses."

Sibly Journal of Engineering for October: "Patent Law and the Engineer," A. C. Bell; "A New Patent Hydraulic Clutch," H. A. Brown; "The Production of Wood Poles;" "Vanadium Alloys," Geo. L. Norris.

Zeitschrift fur den Physikalischen und Chemischen Unterricht for September: "Methodische Versuche auf dem Gebiete der physikalischen Schülerübungen," A. Günthart; "Schattenkurven für das mittlere Deutschland," Grosse; "Ein hydromechanischer Apparat zur Erläuterung einiger beim galvanischen Element auftretenden Erscheinungen," Ehrhardt; "Ein Versuch aus dem Gebiete der magnetischen Kraftlinien," Ehrhardt; "Mikrometerwage für magnetische Messungen," A. Wendler; "Neue Versuche mit dem elektrodynamischen Pendel," Br. Kolbe; "Der Selbstinduktionsversuch von Lodge in einer neuen Anordnung," Br. Thieme; "Kleine Universalbogenlampe mit festem Lichtpunkt für optische Versuche," J. Classen; "Zur Herleitung des Gravitationsgesetzes aus den Keplerschen Gesetzen und umgekehrt nur auf Grund des Energieprinzips," H. Teege. Kline Mitteilungen: "Versuche für Schülerübungen," Gg. Heinrich; "Zentrifugalwage zur experimentellen Bestätigung des Gesetzes $P = \frac{mv^2}{\rho}$," E. Kolig; "Die Drehung der Rolle bei Schwingungen von Fäden," H. J. Oosting; "Ein neuer Apparat zum Nachweis der Spannkraft verschiedener Dämpfe," R. D. Ponomareff; "Die Dekarburierung des Leuchtgases als Vorlesungsversuch," A. Stähler.

Zeitschrift für Mathematischen und Naturwissenschaftlichen Unterricht for September: "Die kinodiaphragmatische Projektion, ein neues Lehrmittel in der Geometrie," E. Papperitz; "Die konstruktive Verwertung einer elementaren einheitlichen Kegelschnittsdefinition," Dr. Rudolf Schüssler; "Zum Beweise des Pascalschen Satzes," A. Schülke.

REDISCOVERY OF LOST MINES.

In addition to discussing deposits of precious stones in the United States, Mr. Sterrett also describes foreign mines and their output. An account is given of the rediscovery of certain lost emerald mines in Colombia. When the Spanish took possession of that country in the sixteenth century the emerald mines of the Indians were seized by them. Excessive cruelties were practiced by the Spanish mine workers on the Indians employed in the mines. In the war of independence of 1816 the country was so desolated that the mines of Cosquez and Somondoco were entirely lost. A Colombian named Francisco Restrep, guided by a few hints given in ancient Spanish parchment maps, and with little or no knowledge of geology or emeralds, undertook the search for the lost emerald mines. In 1896 he found traces of ancient workings and later the large workings of the lost mines. These mines are situated on a ridge of the great eastern range of the Andes, at an elevation of about 9,000 feet above sea level. The great open cuts and tunnels were scattered over an area six miles long and three miles wide.

It is worthy of note that no particular section of the United States has a monopoly of precious stone deposits; for instance, turquoise have been found both in Virginia and in Nevada, sapphires in Indiana and Montana, and topaz in Texas, Colorado, and California.

A copy of the report may be obtained free of charge on application to the Director of the Geological Survey at Washington, D. C.

PROBLEM DEPARTMENT.

By E. L. Brown,
Principal North Side High School, Denver, Colo.

Readers of this magazine are invited to send solutions of the problems in which they are interested. Problems and solutions will be duly credited to their authors. Address all communications to E. L. Brown, 3435 Alcott St., Denver, Colo.

Notice.—No solutions are published in this issue of the journal so that in the future contributors may have a longer period of time in which to solve the problems. Hereafter the solution of a problem will appear in the third number of the journal following that in which it is proposed.

Request.—Readers of this department are requested to send in for solution a new supply of interesting and instructive problems. Algebra problems especially are greatly desired.

PROBLEMS FOR SOLUTION.

Algebra.

270. *Proposed by Letitia Odell, Denver, Colo.*

Factor $x^2-8xy+15y^2+2x-4y-3$.

271. *Proposed by H. E. Trefethen, Waterville, Me.*

If $y^2-yx+1=0$, express y, by means of undeterminate coefficients, in a series of monomials (1) in ascending powers of x; (2) also in descending powers of x.

272. *Selected.*

Let F and F′ denote integral functions, and M/N and M′/N′ proper functions. If $F+M/N\equiv F'+M'/N'$, then $F\equiv F'$ and $M/N\equiv M'/N'$.

Geometry.

273. *Example 71, p. 34, A Course of Plane Geometry for Advanced Students, Part I, by Clement V. Durell.*

Given the incenter, circumcenter, and one excenter of a triangle; construct it.

274. *Proposed by John Gant, Ithaca, N. Y.*

A round hole 1 foot in diameter is cut through a sphere 20 inches in diameter. Find volume of part remaining.

275. *Proposed by H. E. Trefethen, Waterville, Me.*

Divide the triangle whose sides are 7, 15, 20 into two equivalent parts by a radius of the circumcircle.

WELLS IN GRANITE ROCKS.

In the investigation of underground waters in granite rocks in Connecticut by the United States Geological Survey, described in Water Supply Paper 258, it was found that in drilling below a depth of 200 feet the chance of obtaining water greatly decreases. The same conclusion has been reached in the study of granites of Maine. The chances of obtaining a good water supply by drilling in granite range from 95 per cent for wells less than 100 feet deep to only 50 per cent for wells more than 400 feet deep. Those who drill below 200 feet take the risk of incurring more expense than would be involved if they should stop drilling and sink another well 50 or 60 feet distant.

SCIENCE QUESTIONS.

By Franklin T. Jones,
University School, Cleveland, O.

Our readers are invited to propose questions for solution—scientific or pedagogical—and to answer the questions proposed by others or by themselves. Kindly address all communications to Franklin T. Jones, University School, Cleveland, O.

Questions and Problems for Solution.

65. *Proposed by Tom Anderson, General Chemical Co., Cleveland, O.*

If 5.23 grams of brass yield 0.0345 gram of $PbSO_4$, and subsequently 0.0031 gram of PbO_2 on electrolysis of filtrate, what is the per cent of lead in the brass?

[*Ans.*, ½%. Is it correct?]

66. *Proposed by O. R. Sheldon, Chicago, Ill.*

A match may easily set fire to a shaving, but not to a block of the same material. Why?

67. *Proposed by C. A. Perrigo, Dodge, Neb.*

Find the equation, in terms of x and y, for an object projected into empty space with a velocity v and at an angle $\propto$ with the horizontal plane. Compute also its time of flight and range.

68. *Proposed by J. Hawley Aiken, Springfield, Mass.*

What change in volume occurs when cast iron solidifies? As an iron casting cools from its melting point to 20° C., how much would it shrink per foot?

Solutions and Answers.

53. Four kgm. of iron at 400° C. are dropped into 1 kgm. of broken ice and 3 kgm. of water at 0° C. What is the result?

Solution by C. A. Perrigo, Dodge, Neb.

Heat given out by iron = heat taken up by ice in melting + heat absorbed by water.

Let M = mass; T = change in temperature; S = specific heat.

$\therefore$ MTS of iron = 80000 calories + MTS of water.

or $4000(400-x).12=80000+4000(0+x)1.$

$480(400-x)=80000+4000x.$

$192000-480x=80000+4000x.$

$-4480x=-11200,$

$x=25°$, resulting temperature.

59. *Proposed by Tom Anderson, Cleveland, O.*

How many c.c. of aqueous ammonia (sp. gr. 0.96) containing 9.90% NH_3 by weight will be required to precipitate the iron as $Fe(OH)_3$ from 1 gram of $(NH_4)_2SO_4$, $FeSO_4$, 6 H_2O?

[*Ans.*, 1.37 c.c. Is it correct?]

61. (*a*) Calculate the volume of the body of a man who weighs 165 pounds and can float practically submerged in fresh water. Name the unit of volume used.

(*b*) If he were to put on a certain life-belt it would float him 1/10 of the volume of his body out of water, the belt itself being wholly submerged. The specific gravity of the life-belt is 0.25. What is its weight?

Solution by C. A. Perrigo, Dodge, Neb.

(*a*) Since he floats practically submerged, density = 1.

$\therefore$ 165 ÷ 62.5 = 2.48 cu. ft., volume of man.

(*b*) $^1/_{10} \times 2.48$ cu. ft. = .248 cu. ft., volume of preserver.

$$\text{Now Density} = \frac{\text{Mass}}{\text{Volume}} \text{ or } .25 \times 62.5 = \frac{\text{Mass}}{.248}$$

Solving, mass = 3.875 lbs., weight of preserver.

62. (*b*) If an automobile, weighing with its load 2,000 pounds, runs in 3 minutes a distance of 3,300 feet along a grade that rises 5 feet in 100 feet of slope, how much work is done against gravitation?

(*c*) How much *power* is required of the engine in performing the ascent, in excess of the power required to run on a level at the same speed? (Neglect the difference of friction in the two cases.)

Solution by the Editor.

(*b*) Rise is $33 \times 5 = 165$ ft.

Work done is $165 \times 2000 = 330{,}000$ ft. lb.

(*c*) Power is $\dfrac{330000}{33000 \times 3} = 3\frac{1}{3}$ H. P.

Are these answers correct?

Also solved by C. A. Perrigo.

63. In the summer of 1909 a professional catcher caught a baseball that had been dropped from a window of the Washington Monument 500 feet above him. The baseball weighed $^1/_3$ of a pound. Neglecting air resistances,

(*a*) How long was the ball in the air?
(*b*) How fast was it going in miles per hour when it reached him?
(*c*) How much kinetic energy did it have when it reached him?
(In what units is your answer expressed?)

Solution by C. B. Brown, Madisonville, Tenn.

(*a*) Since $S = \frac{1}{2}at^2$ [S=space passed over.]

$$t = \sqrt{\frac{2s}{a}}$$

$$= \sqrt{\frac{2 \times 500}{32.16}} = \sqrt{\frac{1000}{32.16}} = \sqrt{31.094} = 5.56 \text{ sec.}$$ Time ball was in the air.

(*b*) Velocity=acceleration $\times$ time *i. e.* $V = at$

$$= 32.16 \times 5.56$$
$$= 178.8 \text{ ft. per sec.}$$

(*c*) Potential energy=work done in raising ball to height of 500 ft.= force $\times$ distance. $W = Fs$

But kinetic energy=potential energy.

So $E_k = Fs$

$= \frac{1}{3}$ lb. $\times$ 500 ft.

$= 166\frac{2}{3}$ foot pounds.

Also solved by C. A. Perrigo.

64. (*b*) What is the shortest plane mirror which when placed flat against a vertical wall will enable a person 6 feet tall to see his entire length? Illustrate with a diagram.

Answer by C. A. Perrigo.

3 ft.

HISTORIC IRON DEPOSITS.

Description of Early Alabama Mining by United States Geological Survey.

Of historic interest is a pamphlet (Bulletin 470-F) published by the United States Geographical Survey as an advance chapter from "Contributions to Economic Geology, 1910, Part I," on the iron ores in the Montevallo-Columbiana region, Alabama, by Charles Butts. In the course of a geologic survey of the area mapped by the Survey as the Bessemer Quadrangle, Mr. Butts made an examination of a number of ore deposits, chief of which is the noted limonite deposit at Shelby. Actual operations in this section were begun in 1844 with the construction of a furnace having a daily capacity of five tons of cold-blast charcoal pig iron, and work has been practically continuous since that time. The iron made here early acquired a high reputation, and as a result of a comparative test of Alabama, Georgia, and Tennessee irons made at Columbus, Ga., in 1852, an order for 1,000 tons was given, the largest ever placed in Alabama up to that time. A rolling mill was completed in Alabama in 1860, at which armor plates were made for the Confederate Government. The "Merrimac," which for a time created such consternation among the Union warships and which later was a participant in the memorable battle with the "Monitor," was armored with these plates.

In 1863 a larger furnace was built, with a daily capacity of thirty tons. This was equipped with warm-blast ovens and was the first furnace to make warm-blast charcoal iron in Alabama. This furnace was burned in 1865 at the time of Wilson's raid. The output of the two furnaces at Shelby at the present time is about 25,000 tons a year.

PERSONAL NOTE.

At Sendai, a large city in the northeastern part of Japan, has been newly established the Tohoku Imperial University, whence permission has been asked to reproduce Dr. Halsted's "The Bolyai Prize," which appeared in No. 855 and No. 856 of *Science*, "to adorn the starting volumes" of a quarterly journal, as its editor puts it. Meantime, in the capital of the Empire the July number of the Tokio *Butsuri Gakko Zasshi* contains in Japanese Dr. Halsted's article, "The Unverifiable Hypotheses of Science," from Vol. XX of the *Monist*. The July number of the *Open Court* has in it the fifth chapter of Dr. Halsted's book, "On the Foundation and Technic of Arithmetic," entitled, "The Psychology of Reading a Number." The whole book is shortly to appear, published in Chicago.

The French edition de luxe of Dr. Halsted's "Rational Geometry," 296 pages, is issuing from the famous presses of Ganthier-Villars in Paris with a special preface by Laisant, editor of the international review, *L'Enseignement Mathematique.*

But for the Japanese edition, translated by Yoshio Mikami, published by S. Nedsu, Dr. Halsted has himself been asked to write the preface. This is in addition to the preface already promised by Baron Kikuchi, president of Kyoto University, formerly Japan's minister of education, who so royally entertained Dr. Halsted in Japan.

BOOKS RECEIVED.

Revolving Vectors. By George W. Patterson, University of Michigan. Pp. vi+89. 14x22 cm. Cloth. 1911. $1.00, net. The Macmillan Company, New York.

College Physics. By John O. Reed and Karl E. Gathe, University of Michigan. Pp. xxix+622. 15x22 cm. Cloth. 1911. $2.75, net. The Macmillan Company, New York.

Practical Botany. By Joseph Y. Bergen, Harvard University, and Otis W. Caldwell, University of Chicago. Pp. vii+545. 14x20 cm. Cloth. 1911. Ginn & Co., Boston.

Principles of Rural Economics. By Thomas N. Carver, Harvard University. Pp. xx+386. 14x20 cm. Cloth. 1911. $1.30. Ginn & Co., Boston.

The Theory and Practice of Technical Writing. By Samuel C. Earle, Tufts College. Pp. vii+301. 14x19 cm. Cloth. 1911. $1.25, net. The Macmillan Company, New York.

The Elements of Qualitative Analysis, by W. A. Noyes. Sixth edition. 1911. Pp. 133. Henry Holt & Co., New York. Price, $1.10.

A History of the Ancient World, by G. W. Botsford. 1911. Pp. 588. The Macmillan Company, New York. Price, $1.50, net.

A Text-book of Physics, by L. B. Spinney. 1911. Pp. 604. The Macmillan Company, New York. Price, $2.75, net.

Five Hundred Regents Questions in Biology and Zoölogy, with References. 1911. Pp. 41. C. W. Bardeen, Syracuse, N. Y.

Guide to the Insects of Connecticut. Bulletin 16, State Geological and Natural History Survey. Pp. 169+xi. Plates. State Geological Survey, Hartford, Conn.

The School of To-morrow. A Collection of Prize Essays from the *World's Work*. 1911. Pp. 152. Doubleday, Page & Co., New York. Price, $1.00.

Manual of Experimental Physics. By Charles H. Smith, Willis E. Tower and Charles M. Turton, Instructors in Physics, Chicago High Schools. Pp. xxvi+324. 14x19 cm. Cloth. Nov., 1911. Ginn & Co., Boston.

BOOK REVIEWS.

First Year Algebra, by William J. Milne, President of New York State Normal College, Albany, N. Y. Pp. 320. 12x18 cm. 1911. American Book Company.

In developing the topics of first year algebra the simpler phases are presented first and the difficulties are deferred until the pupil has gained some power to cope with them. Simple problems which can be solved both arithmetically and algebraically, and easy solutions of simultaneous equations, are presented early in the course in order to arouse the interest of the pupil. Emphasis is placed on equations and problems. A glance through the book will show that the problems are new and that the author has gone far afield for the facts upon which they are based.

The concrete work is well proportioned to the abstract work. Graphical methods are treated briefly, but they are not made an integral part of the year's work.

H. E. C.

Characteristics of Existing Glaciers, by William Herbert Hobbs, University of Michigan. Pp. ix+301. 17x21 cm. $3.25, net. 1911. The Macmillan Company.

The key to this book is the principle of alimentation and depletion, or the feeding and wasting of the glacier. These in turn depend upon climate. The author finds two types of glaciers. As stated in the preface, "The broad line of cleavage is found to lie between those glaciers which completely cover a considerable portion of the rock surface, and have the form of a flat dome or shield, and the remaining types." From this point of view the author gives a rational, systematic discussion of glaciers which unifies the subject and brings its different parts into proper relations to each other.

Chapter I, "The Cirque and Its Recession," points out, amplifies. and illustrates a distinct contribution to our knowledge of glacial erosion.

Chapter II, "High Level Sculpturing of the Upland," presents phenomena and forces which are not adequately discussed in books upon glaciers, but which are found in the technical literature of the subject and in scattered publications.

Part II, "Arctic Glaciers," and Part III, "Antarctic Glaciers," present those subjects with a fullness and a clearness that throw new light upon the remarkable glaciers in those remote parts of the earth.

In applying the principle of alimentation and depletion the author introduces a new nomenclature. The term "mountain glacier" is given a broader significance than heretofore; it is here made to include all glaciers except ice sheets. For the ice sheet or continental glacier the author uses the term "inland-ice." This term is not defined in the book. Its use seems to be highly objectionable. The terms "ice sheet" and "continental glacier" have a definite meaning and have been long and widely used in the literature on glaciers. "Inland-ice" as used here seems to mean exactly the same thing as these older terms. Moreover, "inland-ice" does not properly designate such ice sheets as those of Greenland and Antarctica. These ice sheets come to the coast, and are not confined to the interior. On the other hand, the other type, namely, mountain glacier, is generally found in the interior of the continents. Ice-caps are intermediate between mountain glaciers and inland-ice.

Notwithstanding this criticism upon the nomenclature, the book takes high rank among the few great books upon glaciers. In recent years much valuable material has appeared upon glaciers in text-books, in monographs, and in separate articles. In 1897 Russell's "Glaciers of North America" appeared, describing the glaciers of a single continent; in 1880 Wright's popular "Ice Age of North America" was published; in 1874 Geike's epoch-making book, "The Great Ice Age," set a new standard for works upon this subject.

The time is ripe for a new setting of the rapidly increasing knowledge of glaciers. Professor Hobbs has made this presentation in a most admirable manner.

Scientists and the general reader will appreciate this book. Technical terms are used when necessary, but the book may be read by any well-educated person.

The references at the end of each chapter are a valuable bibliography. The type in which the book is set is large and clear. The illustrations are well chosen and well made. There are thirty-four plates and one hundred and forty illustrations in the text. It is an informing, interesting, valuable book. J. H. S.

Elements of Zoölogy, to Accompany Field and Laboratory Study of Animals, by Charles Benedict Davenport, Ph.D., Director Department of Experimental Evolution, Carnegie Institution, and of the Biological Laboratory, Brooklyn Institute of Arts and Science, Cold Spring Harbor, Long Island, and Gertrude Crotty Davenport, B.S. Pp. x+507. The Macmillan Company. 1911. $1.25, net.

This revised edition of the Elements of Zoölogy, or "Introduction to Zoölogy," as it was first called, by these authors is a great improvement over the first edition. The laboratory directions have been dropped and the keys also are omitted. Simple keys are useful in secondary zoölogy, but these keys were too technical for high school pupils and are wisely omitted. The authors have undertaken to make each group of animals illustrate some zoölogical principle, problem, or phenomena. This is good so far as it goes, but such treatment is necessarily fragmentary and scarcely adequate for the more important of these phenomena. In many cases the inclusion of the problem in the title is not justified by the treatment of the topic in the chapter that follows. Such topics as adaptation, parasitism, animal associations, etc., are not given with sufficient illustrative material to make an impression upon the mind of the pupil.

Where the text-book is to be used solely as a sort of natural history reference book, this book will answer the need. It is packed full of information about animals. W. W.

The Animals and Man: An Elementary Text-book of Zoölogy and Physiology, by Vernon Lyman Kellogg, Professor in Stanford University. Pp. x+495. Henry Holt & Co. 1911.

The title of this book awakened keen anticipation that at last the ideal zoölogy had arrived, but a very brief inspection sufficed to bring disappointment. Instead of being a well thought out presentation of animals and man in their relation to each other, we find a zoölogy with some chapters of conventional human physiology injected into it. The zoölogy portion has been constructed largely from the author's "Elementary Zoölogy" and "First Lessons in Zoölogy," while the physiology chapters were written by Isabel McCracken.

There is need for a zoölogy which shall carry out the thought of the title of this book in a consistent way, but it is evident that we must wait for it. There should be physiology in a zoölogy, but it should be presented as an integral part of the work, and not superimposed. If the chapters on "Human Structure and Physiology" could be omitted and certain other chapters, as, for example, the one on "Domesticated Animals," expanded, and if a consistent development of the relations of animals and man could be had throughout the book, the author would have a text-book of zoölogy well worthy of a place at the head of the list. We sincerely hope he may be induced to write, not compile, such a book.

However, there are many good points in the book. The chapter on "Animal Physiology" is excellent. The chapter on "Ancient and Modern Man" is something unusual for a zoölogy text-book, but is a good thing. Part V, "Animals in Relation to Each Other, to Plants, and to the Outside World," is good so far as it goes, but is altogether too brief for the importance of the topic. Another chapter is on "Human Diseases Caused by One-celled Animals," and is good, but it suggests a larger topic—human diseases caused by animals—as something much better. There is so much that is good in the book now that we sincerely hope that the author may see his way clear to one more revision. W. W.

Introduction to General Science, with Experiments, by Percy E. Rowell. Pp. xxix+302. 14x19 cm. Cloth. 1911. 75 cents, net. The Macmillan Company, New York.

The author of this book has certainly the right conception of what constitutes the fundamentals of general science. In his selection of topics to be studied he has taken those which sooner or later in the life of the child will be introduced to him in a practical way. The author does not claim that this book is to take the place of any one particular science, but in the selection of the 212 subjects for study the pupil can see the interrelation which exists between the sciences as applied to practical everyday life. The study of this text will undoubtedly stimulate the young pupil with a desire to continue the study of one or more of the sciences. He will get a broad outlook of science in general which will be helpful to him in any event.

The author has been very happy, too, in his selection of the experiments which are to be performed. They are such as come home to the pupil in a very interesting and instructive manner. Each discussion ends with a helpful list of references to texts and books in which the subject is treated to a greater extent. Most of the experiments have been selected from the point of view of making them illustrate an important principle. The method of procedure has been written in such a clear manner that the pupil will have no difficulty in understanding just what to do.

From another point of view the apparatus has been selected so that the cost of the course has been reduced to a minimum. The writer has been unable to discover any serious misstatements of facts in the work and is recommending it as one of the best texts to use in general elementary science.
C. H. S.

The Teaching of Geometry, by David Eugene Smith. Pp. v+339. 13x19 cm. 1911. Price, $1.25. Ginn & Co.

In the part of the book devoted to class-room methods, and so on, the author has brought together and presented in an interesting and instructive manner the many methods and devices commonly used by teachers to arouse the interest of their pupils and to make some applications of the principles of geometry. In addition to this there is a large body of historical matter and a rather comprehensive discussion of the leading propositions in each book of plane and solid geometry.

In other chapters of the book the author proposes "to take up the issues of the present day in the teaching of geometry, in order that we may consider them calmly and dispassionately, and may see where the opportunities for improvement lie." Some problems in arithmetic for solution:

1. If the author uses so many epithets and appellatives in a calm and dispassionate consideration of the present-day issues, how many would he use in a frenzied and passionate consideration?

2. If the real leaders in school life go out into the dust and noisy clamor of "the mob," "the agitator," "the chronic revolutionist," etc., to sift out the grains of gold, how many grains of gold would they have gathered if there had been no "skirmish"?

3. A states that algebra and geometry should not be fused because Latin and Greek cannot be taught simultaneously with advantage. B says that the cases are not parallel. How many times must A affirm and B deny that the cases are parallel, to establish the truth of A's proposition?
H. E. C.

Modern Science Reader. Edited by Robert M. Bird, University of Virginia. Pp. 323. 13x19 cm. Cloth. 1911. $1.25, net. The Macmillan Company, New York.

This book is a compilation of twenty-seven leading articles on chemistry, by nearly as many authors, which have appeared in some of the important journals at comparative recent dates. It provides an interesting and instructive book for that class of readers who have not the time to devote to school work, but desire to improve their spare moments in gaining a knowledge of the chemistry of things of current history. The book will be helpful also to the college man who wishes to secure an epitome of subjects kindred to those upon which he may be working. An idea of the character of the book can be gained when it is stated that such persons as William Crookes, Ira Remsen, Madame Curie, Oliver Lodge, and others of equal caliber have contributed to its pages. It is a work which ought to be in the library of every person who wishes to keep abreast of the times. C. H. S.

Plane and Spherical Trigonometry, by John Gale Hun and Charles Ranald MacInnes. Pp. VII+205. 14x22 cm. 1911. Price, $1.35. The Macmillan Company.

It was the aim of the authors to present the essentials of trigonometry with clean-cut brevity, and they have confined the treatment of plane trigonometry to 65 pages and spherical trigonometry to 26 pages. More space than usual is given to drawing graphs of simple equations in polar coördinates. The line values of the functions are used as little as possible. The type is large and clear, and the pages are well arranged. The tables of logarithms can be read without tiring the eyes, since the figures are printed clearly and are well spaced. H. E. C.

Monographs on Topics of Modern Mathematics Relevant to the Elementary Field, edited by J. W. A. Young. Pp. VIII+416. 16x23 cm. 1911. Price, $3.00. Longmans, Green & Co.

The teacher of elementary mathematics who wishes to get a view of the mathematical region which lies just beyond the field in which he toils will be deeply interested in these monographs.

They contain: "(1) A considerable body of results proved in full, so that the reader can materially extend his mathematical acquisitions by the reading of the monograph alone. (2) Statement without proof of some leading methods and results, so as to give a bird's-eye view of the subject. (3) A small number of references indicating what the reader may profitably take up after he has mastered the contents of the monograph."

The titles and authors of the monographs are: I. The Foundations of Geometry, by Oswald Veblen. II. Modern Pure Geometry, by Thomas F. Holgate. III. Non-Euclidian Geometry, by Frederick S. Woods. IV. The Fundamental Propositions of Algebra, by Edward V. Huntington. V. The Algebraic Equation, by G. A. Miller. VI. The Function Concept and the Fundamental Notions of the Calculus, by Gilbert Ames Bliss. VII. The Theory of Numbers, by J. W. A. Young. VIII. The constructions with Ruler and Compasses; Regular Polygons, by L. E. Dickson. IX. The History and Transcendence of π, by David Eugene Smith.

A large part of the book requires of the reader only a knowledge of elementary algebra and geometry, and a fair degree of mathematical maturity. A careful study of these monographs will give a teacher a more complete understanding of his own field of mathematical endeavor as well as a broader outlook. H. E. C.

Elements of Plane Trigonometry, by Daniel A. Murray, Professor of Applied Mathematics in McGill University. Pp. IX+136. 13x21 cm. 1911. Longmans, Green & Co.

This book presents the portion of trigonometry required in the solution of the problems that arise in ordinary engineering. Radian measure, the periodicity of the trigonometric functions, their general values, and their graphs, and the inverse trigonometric functions are discussed in the earlier chapters.

The line definitions of the functions are explained fully, and the unit circle is used to a considerable extent. The text-book is well adapted to the requirements of a short course in trigonometry. A six inch cardboard protractor is bound in the book.
H. E. C.

Plane Geometry, by C. A. Hart, Instructor of Mathematics, Wadleigh High School, New York City, and Daniel D. Feldman, Head of the Department of Mathematics, Erasmus Hall High School, Brooklyn, with the editorial coöperation of Professors Tanner and Snyder, Cornell University. Pp. viii+307. 13x19 cm. 1911. American Book Company.

The authors call attention to these leading features of the book: (1) The parallel form of proof, argument on one side of a vertical line and reasons on the other side. (2) Definitions that carry a real meaning, that are clear, accurate, and in accord with the best usage of to-day. (3) The arrangement, simplest concepts first. (4) Numerical problems placed immediately after theorems of which they are applications. (5) The careful selection and arrangement of exercises. (6) The full discussion of loci. (7) The discussion of incommensurable magnitudes and of limits. (8) The discussion of areas, not only more rigorous but also more natural and pedagogical than the usual presentation.

The division of the argument of each proof into concise and numbered steps is a most excellent arrangement, if one must use a book that gives proofs in full. It seems as if pupils would have much less difficulty in grasping the treatment of areas as here given than they have with the usual presentation.
H. E. C.

Practical Botany, by J. Y. Bergen and O. W. Caldwell. Pp. vii+545. 13×19 cm. 1911. Price, $1.30. Ginn & Co., Boston.

Teachers of botany have somewhat tardily come to realize that the high school pupil cares little for anything unless he can see some practical aspect to it. The old-fashioned, childish courses awaken neither his admiration nor even his respect; on the other hand, the more technical courses sometimes leave him bewildered in an uncomfortable maze or details. Teachers will be glad to note, therefore, the appearance of the new Practical Botany which has been written to meet the present situation. The Bergen texts have enjoyed such an enviable reputation that the advent of a new one at once attracts interest. Mr. Bergen and Dr. Caldwell have, apparently, recast entirely the subject matter of the earlier botanies and added much new material, keeping the utility aspect always in the foreground.

In common with other recent texts, this one possesses the good quality of having an abundance of subject matter. Botany generally comes early in the high school curriculum—before the average pupil is able to appreciate the true value of laboratory work. He has been accustomed to learning from books, and he ought to have considerable text work in his botany. It is a relief, then, to find in this text a large amount of material that can be assigned. The authors have left to the teacher the manner of laboratory presentation, so the teacher is not embarassed by having the text omit entirely discussion of much that he con-

siders important in laboratory work, or by having it treated so briefly that a text assignment is a useless repetition. Every teacher finds occasions when it is difficult to keep his laboratory work in advance of his text assignment. There is much in this new book that requires no particular sequence in assignment that could be used admirably. The chapters devoted to a discussion of some of the leading families of flowering plants, and their uses, timber and forestry, plant industries, and weeds are of especial interest in this respect. They are also true to the purpose of the book. The incentive to collateral reading is added, too, by the bibliographies given from time to time.

A matter of extreme importance from the pupil's point of view is the diction. The pupil is only too ready to complain that the text is too hard and he cannot understand it. This text is written with great clearness. There are some unfortunate adjectives used in descriptions, but not many.

The illustrations are unquestionably the finest to be found in any botany text for secondary schools. They are well chosen in number, so that the book nowhere appears "loaded," and in clearness of reproduction, they leave little to be desired. The figures of the "cedar apple," Marchantia thallus, cross sections of Pteris rhizome and pine needle leaf give much credit to the illustrators, as combining with accuracy in detail much artistic ability. Many of the half tones are also remarkably clear.

The order in which the subject matter is presented is new. Chapter I, entitled "Introductory—Plants in Nature," well brings out the significance of plants. Chapter II, "General Structure and Work of Plants," is supposed to be a preliminary observation of plant structures and plant activities. The method is logical, but the execution of it is a stupendous task, and this chapter does not appear to be an entire success. It would have been more successful, probably, if it had been treated in nine pages instead of nineteen. To speak of "cytoplasm" so early as page eight makes one shudder; turgidity, the names of the parts of the pistil, and other similar details, though possibly they seem necessary in an introductory chapter, would be more effective elsewhere. The paragraph on respiration is one of the finest in the book. This phenomenon in most texts is treated in a very superficial manner, but here is an exceptionally clear statement of it, so far as we can understand it to-day. One fears that the pupil so early in the course would not appreciate its excellence. While, undoubtedly, it was the author's idea that parts of this chapter should be re-assigned as occasion demands, it seems to the reviewer that several of the subjects would have had greater value if treated ever so slightly in this chapter, and then had the dignity of short chapters by themselves at a later stage in the book.

The chapters on the plant groups show careful selection of material. A chapter of the length of twenty pages on bacteria is a welcome innovation and is in harmony with the purpose of the text. One is perhaps a little surprised that the brown algae are treated so briefly as in one and one-half pages.

Practical Botany, then, seems to be a real contribution to the teaching of botany in secondary schools. The practical aspect predominates throughout. The authors are to be congratulated upon their success. It is a very usable text and teachers will find it suited for high school use. It can readily be adapted to half-year or year courses. No one who has examined this text can say that it is fitted only for high school seniors or university freshmen.

C. H. Sackett.

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